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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A three-unit MUST shelter was fabricated of double-wall sections, each consisting of a single piece of fabric produced by a three-dimensional weaving technique. The program consisted of developing this technique, as well as a method for spray-coating the exposed surfaces with synthetic rubber compounds equivalent to standard MUST shelter specifications. This report provides an assessment of the developed materials, processing equipment, and fabrication methods used in producing the shelter sections.		

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20. ABSTRACT continued

It describes problems encountered, design changes required to accommodate the newly developed inflatable structure. It discusses testing procedures and results, inspection and quality assurance provisions. Limitations of the new system together with recommendations for future improvement or corrective action are also discussed.

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PREFACE

This report summarizes work accomplished by the Aero-Mechanical Engineering Laboratory, (AMEL), Shelters Engineering Division under contract number DAAG17-73-C-0139 with the B. F. Goodrich Engineered Systems Co.

A three-unit MUST shelter was fabricated of double-wall sections, each consisting of a single piece of fabric produced by a three-dimensional weaving technique as well as a method for spray-coating the exposed surfaces with synthetic rubber compounds equivalent to standard MUST shelter specifications. Technical Report No. TR 7T-7-AMEL, provides details covering the project.

This report provides an assessment of the developed materials, processing equipment and fabrication methods used in producing the shelter sections. It describes problems encountered, and design changes required to accommodate the newly developed inflatable structure. It discusses testing procedures and results, inspection and quality assurance provisions. Limitations of the new system together with recommendations for future improvement or corrective action are also discussed.

Mr. Donald B. Shaw of the Aero-Mechanical Engineering Laboratory served as Project Manager. Mr. Stanley J. Shurtleff of the Clothing, Equipment and Materials Engineering Laboratory assisted in the evaluation of material and coating techniques.

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EVALUATION REPORT OF THE DOUBLE WALL AIR INFLATED
MUST SHELTER - CDRL SEQUENCE NUMBER 2

1.0 INTRODUCTION

1.1 Objective

1.1.1 The objective of this program was to develop air-inflatable, double-wall, hospital shelter sections (medical unit, self-contained, transportable, MUST), including double-wall casings of three dimensional (3-D) woven fabric. These shelter units should functionally and dimensionally correspond to conventionally fabricated MUST units.

In order to accomplish this objective, it was necessary to:

- a. Produce and evaluate integrally woven, double-wall, 3-D fabric for inflatable structure casings.
- b. Develop suitable coatings, materials, equipment, and techniques for application of these synthetic coatings to the 3-Dimensionally integrally woven double-wall casings. Casing properties to be comparable to the MIL-C-43285B specification requirements.*

1.1.2 The evaluation of the weaving technique, tooling, and equipment was conducted by Woven Structures Company which developed and produced the 3-Dimensionally woven fabric casings. Their report was enclosed in the Appendix of the Manufacturing Methods Report, Ref. 1.

1.1.3 The development and evaluation of synthetic coatings, equipment, and tooling for the coating, and assembly of the MUST shelter sections was conducted by the New Product Development of the B.F. Goodrich Engineered Systems Company (BFGESC), a division of The B.F. Goodrich Company (BFG).

1.1.4 The New Products Development Department was responsible for overall fabrication, testing evaluation of all materials and components and report preparation. The test samples were prepared by departmental laboratory technicians and were tested in BFG corporate Physical Testing Laboratories in Akron, Ohio.

1.1.5 The coating and fabrication of the MUST shelter sections were accomplished in the BFGESC Grantsville, West Virginia Plant. The testing of sections, hardware, components, subsystems, and systems was also done at the Grantsville, West Virginia Plant.

1.1.6 Some of the materials and hardware used in this development program were identical to those used in the conventionally fabricated MUST shelters and, therefore, were not individually tested. However, whenever these were used in an assembly or in a subassembly, they were functionally tested together with the assembly or sub-assembly.

* MIL-C-43285B Military Specification. "Cloth, Coated (Chloroprene Base Coated Chlorosulphonated Polyethylene Top Coated)", Dated 2 August 1968.

1.1.7 This report chronologically assesses the results of materials tests and equipment performance. The material test results were compared with the requirements of MIL-C-43285B and the Natick Laboratories Limited Production Purchase Description (LP/P. DES) 42-70. Positive and negative aspects are discussed and recommendations for improvements of materials and manufacturing processes are made.

1.2 Identification of Personnel

The design, fabrication, and testing was assigned to Mr. I. I. Straga, as Project Engineer, under the direction of Mr. C.P. Krupp, Manager, New Products Development. Mr. Tony Petrosino supervised the fabrication and assembly at the plant in Grantsville, West Virginia.

Technical representatives of the US Army Natick Laboratories assigned to this project by the contracting officer were Messrs. D. Shaw, as Project Manager, and S. Shurtleff, in charge of Material Evaluation.

2.0 DEVELOPMENT PROGRAM

2.1 Material Requirements

Government Contract No. DAAG 17-73-C-0139 specifies that the coating of the 3-Dimensional woven fabric casing arches must be accomplished by using a Neoprene-latex base coat with a Hypalon top coat.

The coating system was compounded with the goal of meeting all physical requirements stated in the Military Specification MIL-C-43285B. In addition to that specification, the requirements of U.S. Army LP/P. DES 42-70 of September 1, 1970, applied. LP/P. DES 42-70 is the U.S. Army Document which states the requirements for the procurement of the conventional fabricated MUST shelters.

All tests specified in the above documents were to be performed by the contractor with the exception of three tests which would be performed by the US Army Natick Laboratories.

The tests to be performed by the Natick Laboratories were:

1. Abrasion test per Method 5302, Fed. Std.-191.
2. Tear strength per Method 5132, Fed. Std.-191.
3. Hydrostatic test per Method 5512, Fed. Std.-191.

A sufficient amount of material was supplied from each coated section to Natick Laboratories for these three tests.

2.2 Selection of the Neoprene-latex Compound

- 2.2.1 A Neoprene-latex coating was compounded with the objective of meeting the physical properties required per Specification MIL-C-43285B. During the first tests, it was found that the compound would not pass the flame-resistance test due to excessive after-flame time. A flame retardant material, antimony oxide, was added to increase the flame resistance. The new latex compound passed the flame resistance requirements.

This latex compound had a viscosity of 25 to 35 seconds when measured in a No. 4 Zahn cup. It contained 50% solids (latex, pigment and curing agent). The latex compound when brushed on the fabric cured in 30 minutes at 300°F. It also cured at an ambient temperature and humidity in 1.5 to 2 hours; however, successive coats could be applied after 45 to 60 minutes.

- 2.2.2 This latex compound was identified as BFG No. 190-X-63112. A test program was conducted to verify that the coating would be satisfactory for coating the full size sections.

- 2.2.3 The first sample was made by brushing the Neoprene-latex over the woven arched fabric supplied by the Woven Structure Company.

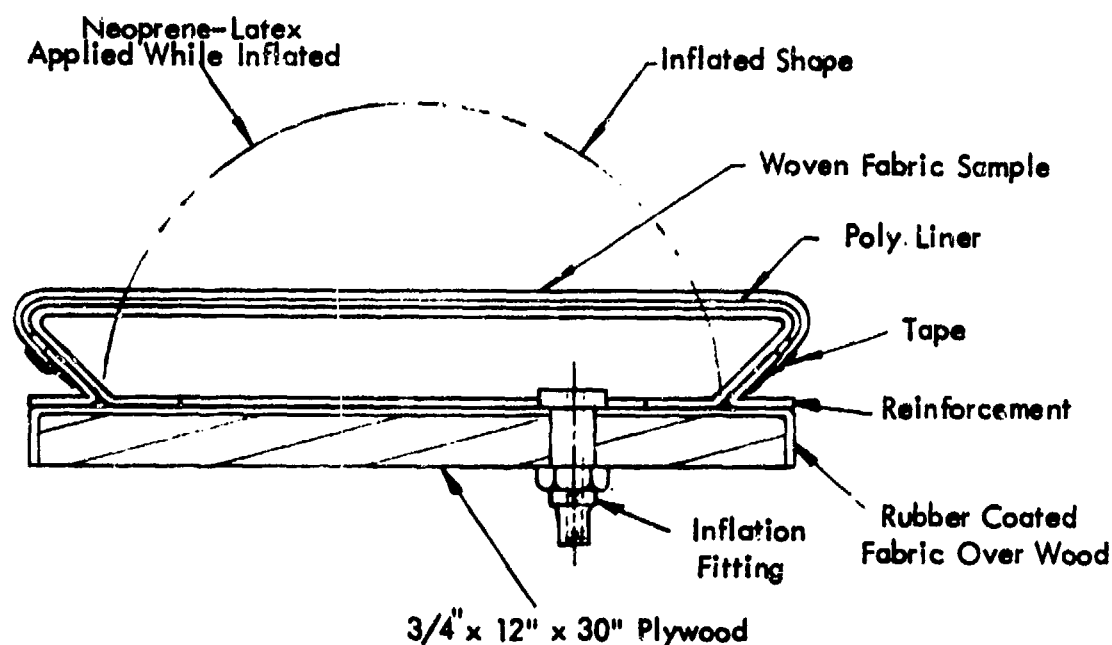
- 2.2.3.1 The samples were made over a pillow type base as shown in the sketch on the next page.

Conditions similar to those which would be present in full scale production were simulated as closely as possible for the fabrication of the test samples. These were as follows:

- a. The pillow inflated to 0.5 psi.
- b. A sheet of polyethylene release film between the fabric and the inflation bag.
- c. The fabric surface smooth and tensioned in both directions.
- d. The coating was applied by brush or roller with the sample held in the vertical position.

2.2.3.2 To obtain a reasonably good coated surface, eight successive coats of Neoprene-latex were required. The coated thickness averaged 0.034" or about 0.002" per coat. Each coat required 45-60 minutes to cure before the next coat could be applied.

2.2.3.3 A coat of white Hypalon was applied over the Neoprene-latex surface. This coat was followed by an olive green or pale green Hypalon as the top coat.



2.2.3.4 The application of Neoprene-latex by brush or hand roller did not leave a good pinhole free surface. Therefore, the surface had to be retouched several times until a pinhole free surface was obtained.

This method of hand application was good for small trial samples, but would be time consuming for application on a large full-size woven section. Therefore, a more economical method of coating was sought.

2.2.3.5 From the coated samples, the appropriate size test samples were cut out and tested per MIL-C-43285B Specification.

2.3 Laboratory Testing of Neoprene-latex Test Samples

2.3.1 Weight Per Method 5041, Fed. Std.-191.

The test samples prepared by the brush method weighed 2.47 ounces per square yard per coat. Eight coats of Neoprene-latex measured 0.0197 inches thick. The total thickness of fabric and coating was 0.037 inches. The average weight was 36 to 37 ounces per square yard. The average weight of the brush coated fabric was more than the weight of standard MUST shelter coated fabric walls, which was 13 to 15 ounces per square yard.

2.3.2 Breaking Strength, Method 5102 Federal Standard 191. Several samples were tested for their breaking strength. They failed at an average of 300 pounds per inch of width in warp and 190 pounds per inch of width in the fill direction.

2.3.3 Adherability - Coated Cloth Test

2.3.3.1 Lap seam samples were fabricated per LP/P. DES 42-70, Par. 4.4.1.1, using the following adhesives:

- a. Bostik 1039 with Boscodur No. 5, produced by Bostik Chemical of USM Corp.
- b. N-136-B & A UBAGRIP, produced by Staley Chemical Company.

The samples were tested per LP/P. DES 42-70 paragraph 4.4.1.4.1 (standard conditions) and per paragraph 4.4.1.4.2 at elevated temperature.

All samples made and bonded with Bostik or UBAGRIP Adhesive passed the ambient temperature test: four hours at $65\% \pm 2\%$ relative humidity at temperature of $70^{\circ}\text{F} \pm 2^{\circ}\text{F}$ when loaded to 40 pounds per inch tension.

The above samples also passed the elevated temperature test of $200^{\circ}\text{F} \pm 2^{\circ}\text{F}$ for four hours without slippage.

Because all results made with either Bostik 1039 or UBAGRIP N-136 were the same, the decision was made to use Staley UBAGRIP Adhesive N-136 B & A. Our Grantsville Plant, where the MUST sections would be fabricated, used the same adhesive to bond similar fabrics and products for years with great success.

2.4 Laboratory Tests of Purchased Fabrics

2.4.1 Purchased fabrics bought per specification and used for floors, inner bands, weather strips, end panels, reinforcement patches, and other auxiliary components of the MUST shelters have been tested for their physical properties. All samples made with these fabrics passed the MIL-C-43285B specification requirements.

2.4.2 The samples passed the adherability tests when bonded to themselves; therefore, no additional test samples were fabricated and tested.

2.4.3 Emphasis was placed on bonding of the purchased materials to the spray coated fabric to either olive green or pale green surfaces, since these are the only fabric bonding combinations that occur in the full size MUST shelter.

2.5 Selection of the Hypalon Outer Coats

2.5.1 A B.F. Goodrich compound, "Radalon", which met the requirements of the MIL-P-9503-B for the outer weather resistant coating was selected for the top coating material. These coatings are manufactured and sold for coating Neoprene coated fabrics to provide protection from weathering and ozone.

2.5.2 The physical properties of this coating compound are listed below:

Compound Properties, A-625-B (White "Radalon")

Base	Hypalon* Rubber
Color	White
Viscosity	Ford Cup $\frac{1}{2}$ " Orifice 8 to 15 seconds at 75°F
Total Solids	24 to 26%
Specific Gravity	1.00 (Calculated)
Thinner	Toluol or Xylol
Flash Point	44°F (Approximate)
Coverage -	
Calculated	230 sq. ft./gal./mil.
Application Average	150 sq. ft./gal./mil.

*Hypalon DuPont Trade Name

2.5.3 When color pigments were added to the A-625-B "Radalon" to produce the olive green and pale green top coatings, the top coating 0500 BH 272 (Olive Green) and 0500 BH 273 (Pale Green) matched the colors of the Fed. Color Standard No. 595.

2.5.4 "Radalon" cures slowly when exposed to air. For faster rate of cure, A-1202-B was added to "Radalon" in ratio of 4 fluid ounces of A-1202-B to one gallon of "Radalon". The accelerated cure allowed removal of the sprayed sections from the support stand with minimum risk of surface blocking or physical damage from handling 24 hours after final coating was applied.

2.5.5 The top coat system for both inside and outside surfaces was a two coat system. A white coat was applied first. The white "Radalon" had the function of neutralizing the black Neoprene-latex surface before the olive green or pale green coating was applied. This was necessary to obtain a true color match for the outside and inside surfaces.

- 2.5.5.1 All the "Radalon" coatings are sprayable. The coatings were diluted with toluol in ratio of 2/3 of coating to 1/3 of toluol for best results in spraying.

Standard DeVilbiss Model JGA-502 with tip No. 74 spray equipment was used to spray the coatings. The atomizing air pressure was 70 psi with 50 psi air pressure in the fluid container.

- 2.5.5.2 One heavy spray coat of white "Radalon" followed by either two light coats or one heavy coat of olive green or pale green was sufficient for complete coverage of the outer and inner MUST shelter surfaces. A minimum time of 15 minutes should elapse between application of successive spray coats.

2.6 Development of Spray Equipment for Neoprene-latex Application

The application of the Neoprene-latex compound to the woven fabric surfaces by brush and hand roller proved to be slow and economically not feasible for large surfaces. A better method of application was sought which would be practical for production quantities of shelters. Analysis of the coating application problems indicated the most economical method of application would be by spraying. Various suppliers of spray equipment were contacted and several types of equipment were evaluated. The principal application problem in spraying the Neoprene-latex was the tendency to coagulate due to shear force during the spraying or pumping operation. Changes in the Neoprene-latex did not improve this condition. It was apparent that a system for spraying would have to be developed which would not subject the latex to high shear forces during the spraying operation.

All commercially available spray equipment was unsatisfactory for application of the Neoprene-latex coating. The principle cause of failure was due to the high shear force causing coagulation of latex in the valves of the spray system. Some systems would spray satisfactorily for a short period of time and then clog. All systems produced a good surface on the coated fabric.

Spray equipment was designed by B.F. Goodrich engineers which eliminated the shear force problem in the latex. This equipment proved to be successful with no coagulation problems and was used to spray coat the three test shelter units. This equipment is described in detail in paragraph 2.6.4.

2.6.1 Standard Air Atomized Spray Equipment

Several standard paint spray guns of the air atomized type were recommended by vendors of spray equipment. These were evaluated either at the vendor's plant or at B.F. Goodrich. (Vendor recommended nozzles, air caps, and spraying pressure conditions were evaluated.)

- 2.6.1.1 A DeVilbiss spray gun, type MBC, Model "L", was evaluated using 80 psi air pressure in the gun and 0 to 30 psi air pressure in the fluid container. Although the equipment did spray the material, the delivery rate was low and the pressure was not adequate to properly atomize the viscous Neoprene-latex resulting in a very rough surface.
- 2.6.1.2 A DeVilbiss spray gun EGA, Model 502, was tried with several nozzle combinations. It too, produced an unsatisfactory surface due to poor atomization.
- 2.6.1.3 A Binks #18 spray gun, equipped with #66 fluid nozzle and #66 SD air cap, produced results similar to that obtained with the DeVilbiss gun.
- 2.6.1.4 All of these standard air-atomized spray guns were not designed for high air pressure to adequately atomize the high-viscosity Neoprene-latex. Tests were made with the Neoprene-latex diluted with distilled water in amounts of 25 percent, 50 percent, and 100 percent of the original Neoprene-latex volume, in an attempt to improve the flow of the material. Although this reduced the viscosity, it also lengthened the drying time between coats. The poor surface obtained with air-atomized spray equipment and the low delivery rate caused us to abandon this approach as a means of applying the Neoprene-latex. However, this type of equipment was found to be satisfactory for applying the Hypalon top coating which was solvent based.

2.6.2 Airless Spray Equipment

Two basic types of airless spray equipment were investigated: (1) air operated piston pump equipment and (2) electric motor driven diaphragm pump equipment.

Airless spray equipment is particularly suited for spraying high viscosity materials of all types at high rates of delivery with little or no overspray. We thought that this type of equipment could be used in spraying the Neoprene-latex without dilution and produce a satisfactory surface.

2.6.2.1 Air Operated Piston Pump Airless Spray Equipment

A "Nordson" Model 64A single piston high pressure pump was evaluated using "Nordson" Model L and Model C-73 spray guns. The evaluation involved tips with 0.014", 0.009" and 0.006" wide orifices. The pump piston to air supply ratio of this unit was 15 to 1. With 80 psi factory air line pressure, 1,200 psi field pressure was obtained at the guns tip.

The equipment worked reasonably well but delivered an uneven sprayed surface, full of minute air bubbles. Different size tips did not produce a significant improvement in the appearance of the sprayed surface. The smaller orifices reduced the amount of Neoprene-latex delivered to the surface. This equipment

did not provide sufficient pressure to adequately atomize the Neoprene-latex. Personnel of The B.F. Goodrich Adhesive Laboratory investigated the use of a similar single piston pump made by the Graco Company, but their results were no improvement over those obtained using the "Nordson" equipment.

2.6.2.2

Diaphragm Pump Airless Equipment

The equipment from two different manufacturers of high pressure diaphragm pumps were then evaluated.

The "Pulsa Feeder" Type CPD-3 pump made by Lapp Insulator Co. is a high-pressure hydraulic pump which at an operation pressure of 3000 psi will deliver 1.75 gallons of fluid per hour. The maximum pressure rating is 3750 psi. The pump consists of two electric motors each driving a piston 0.25 inch in diameter which reciprocates against a hydraulic fluid contained in a reservoir which in turn pulsates a diaphragm which pumps the material to be sprayed.

This equipment demonstrated very low delivery rate when spraying the Neoprene-latex compound and was not considered further.

2.6.2.3

A Wagner Model ST-2700 pump produced by the Spray-Tech. Co. of Minneapolis, Minnesota, was used with a Graco high pressure (5000 psi rating) airless gun in the next series of tests that gave encouraging results. This combination of pump and gun produced an excellent sprayed surface and delivered material at a high rate. Theoretically, it could deliver up to 1.25 gallons per minute at 3300 psi. Good Neoprene-latex atomization was obtained with fluid pressure of 2000 to 3000 psi. In these tests, a 150-square-foot area was sprayed in five minutes for an average of 30 square feet per minute coverage rate. Since we had trouble with the Neoprene-latex coagulating in the pump of the "Nordson" pump it was decided to run a prolonged test to determine if coagulation would occur with this equipment as well. To test the equipment, the pump was allowed to run for an extended period of time. After one hour, the rate of Neoprene-latex delivery decreased, and after two hours latex coagulated within the pump causing the pump to overheat. It required several hours to partially disassemble the pump and clean it. The pressure relief valve in the pump which contains a 1/32 inch diameter orifice was completely plugged. To avoid this condition, the manufacturer suggested that we by-pass the pressure relief valve. A new part was sent from the factory with the relief valve removed, and the pump was retested. After one-half hour, the pump ceased to work. It was taken apart and a 1/8 inch thick disc of coagulated Neoprene-latex was found under the diaphragm.

We believe that a part of the accumulated Neoprene-latex under the diaphragm was formed during the first test and part during the second test, and it was

coagulated by heat generated by the rapid oscillation of the pump diaphragm. The Neoprene-latex build-up prevented fresh compound from being sucked into the pump.

The Wagner ST-2700 airless pump was not considered satisfactory for use in spraying Neoprene-latex over a prolonged period of time because of the excessive maintenance which would be required. Although this type of equipment was not found to be satisfactory for applying the Neoprene-latex, it would be ideal for applying Hypalon or other low viscosity coatings because of its high delivery rate and minimum overspray. This equipment is compact and can be carried by one person. A hose up to 300 feet long can be attached to the pump and still provide adequate flow rate at the gun.

2.6.3

Airless Spraying using Pressure Accumulator with Bladder

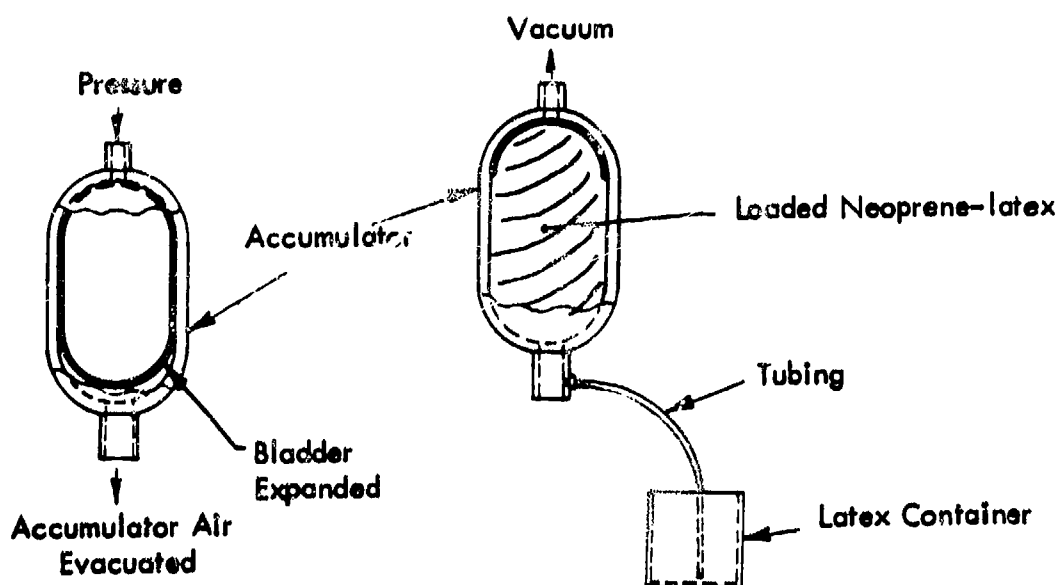
Our investigation of commercially available pumps for airless spraying brought us to two conclusions:

- a. The Neoprene-latex coating could be effectively sprayed using airless spray equipment if pressures above 1500 psi is used.
- b. Since commercially available high pressure pump equipment caused the Neoprene-latex to coagulate, special equipment would have to be custom-built for this purpose. Such equipment would have to be able to produce the high pressure required for complete atomization of the highly viscous compound and should not include moving parts or small openings that could become clogged with Neoprene-latex due to shear of the liquid.

To meet these requirements, we first proposed to use a pressure vessel filled with Neoprene-latex pressurized with nitrogen gas at the proper pressure for spraying. Under pressure, the Neoprene-latex would flow unobstructed from the vessel, through the hose, and into the spray gun. This setup, we expected, would minimize the possible Neoprene-latex coagulations. A study by our latex technical group showed that at very high pressures (3000 psi) the Neoprene-latex would absorb up to 2.50 times its own volume in nitrogen. This could cause the Neoprene-latex compound to foam as the pressure is released at the spray gun nozzle and sprayed unto the surface to be coated. Therefore, to work properly, this device would need some means of separating the nitrogen from the coating compound. We decided to evaluate a Greer-Hydraulics Corporation Standard Hydraulic Pressure Accumulator which contains a bladder which separates the hydraulic fluid from the pressurizing gas as a pressure source for spraying. Its design seemed suited to our requirements and one of their standard five-gallon models was purchased for use as the pressure source for airless spraying.

B.F. Goodrich Drawing No. 5X2082 schematically illustrates the assembly of this modified pressure source. (See Figure 1). The pressure vessel was connected through a ball valve and fluid filter to 50 feet of $\frac{1}{4}$ inch high pressure hose, which was connected to the spray gun. One or more bottles of nitrogen gas was used to provide the pressure required to force the Neoprene-latex from the opposite side of the bladder in the accumulator through the hose and out of the tip of the spray gun in an unrestricted flow. Since there were no moving parts to cause friction as the spray compound is delivered to the airless spray gun, we did not expect problems with Neoprene-latex coagulation.

Loading the spray compound into the pressure vessel through the small bottom opening that contained a check valve was found to be difficult. By adding a second ball valve and a three foot-section of copper tubing, $\frac{5}{16}$ inch in diameter, as shown in Figure No. 2, we were able to load the Neoprene-latex into the accumulator by first expanding the bladder with air pressure which forced all of the air from the accumulator. Once this was done, the copper tubing was inserted into the spray compound and the air in the diaphragm released. This action created a vacuum which sucked the compound into the accumulator below the diaphragm. When the diaphragm returned to its unstretched condition, a vacuum was drawn on the diaphragm which completed the filling of the accumulator with Neoprene-latex. See sketch.



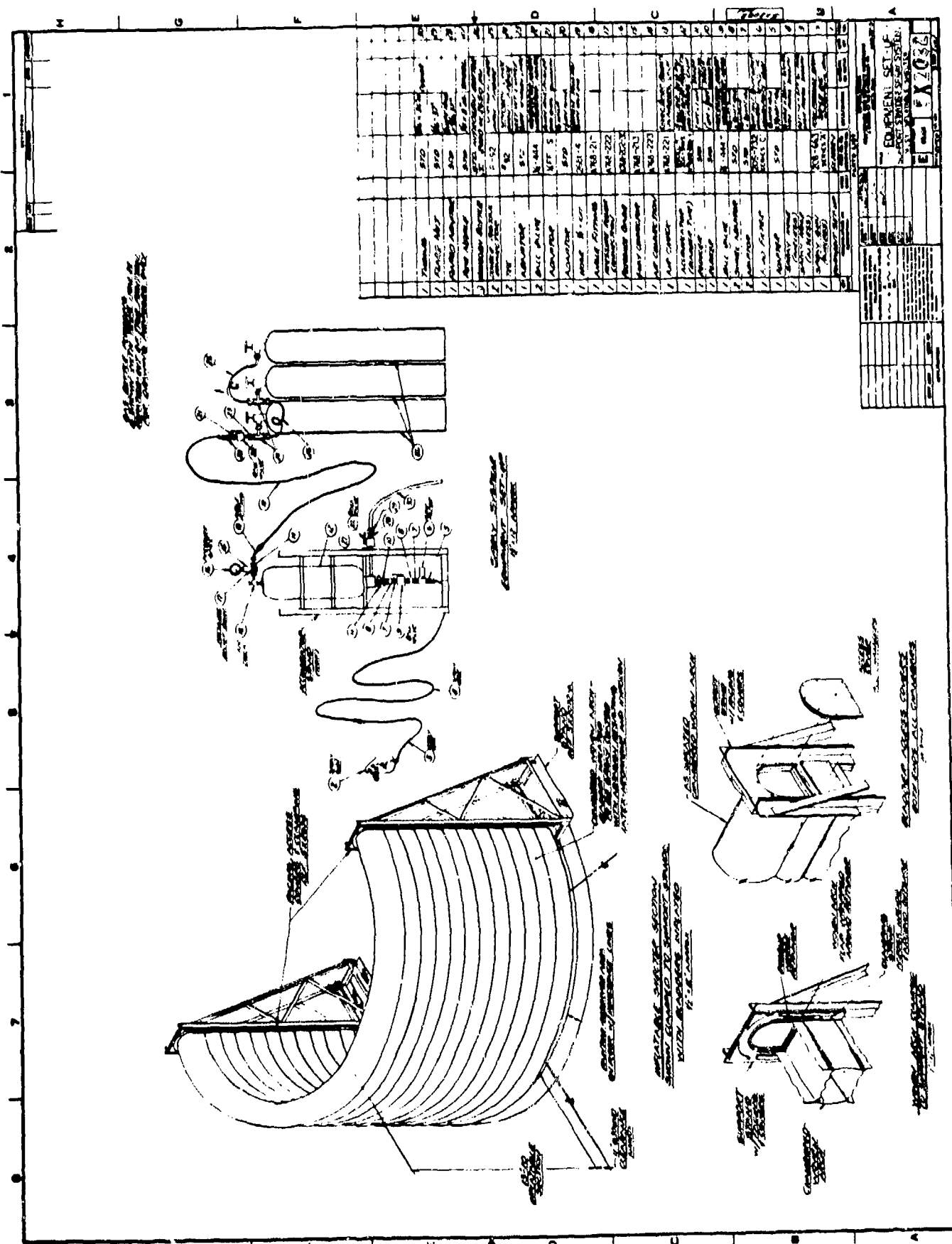


FIGURE 1: SPRAY SYSTEM AND SUPPORT STAND



FIGURE 2: SUCTION OF NEOPRENE-LATEX INTO
THE BLADDER ACCUMULATOR

Once the spray compound was loaded into the accumulator, pressure was applied to the top side of the diaphragm from one or more bottles of high-pressure nitrogen gas through a hose equipped with a check valve and pressure gage. The equipment was then ready for spraying.

To activate this unit, the pressure regulator valve on the nitrogen bottle was set to the desired pressure and the flow valve opened to pressurize the Neoprene-latex spray compound.

We found that the equipment worked best when a pressure above 2000 was used which reconfirmed the experience with the Wagner equipment, but a good spray pattern could be obtained at a pressure as low as 1500 psi.

2.7 Laboratory Coating Trials with Spray Equipment

2.7.1 The laboratory coating trials were conducted with the spray equipment described in paragraph 2.6.3. Small pieces of fabric from the first small section woven were mounted on a test fixture for spraying. Test specimens were cut from the coated fabric and evaluated against the requirements of MIL-C-43285B.

2.7.2 The spray equipment worked satisfactorily producing a thickness build-up per coat of 0.002 inches.

After several coats were sprayed, some surface irregularities were evident. The coverage was complete over a majority of the area; however, pinholes were visible between some yarns, and the surface coating was uneven where repairs in the fabric had been made to correct errors in weaving. The opening between yarns was larger at the juncture of the web with the inner and outer wall of the woven fabric. This was caused by the change in picks per inch where web picks are terminated. These openings were accentuated when tension was placed on the yarns by the inflation of bladders. See Figure 3.

Several brush coats of the Neoprene-latex compound were required to close these openings before the remaining spray coats were applied. See Figure 4.

2.7.3 The yarns were treated with dip solutions before weaving to obtain adhesion between the coating material and the woven fabric. The original plans were to treat the yarns with a solvent based P.A.P.I. solution which would be followed by a second dip in a Neoprene-RFL solution. The Bibb Company, of Macon, Georgia, could not handle the solvent based P.A.P.I. solution; therefore, an aqueous pre-dip solution had to be developed. This caused several weeks delay, but proved to be satisfactory for adhesion of coating to fabric.

The treated yarns were fairly stiff and were tightly bound together causing some problems in weaving. The test samples evaluated indicated material woven from

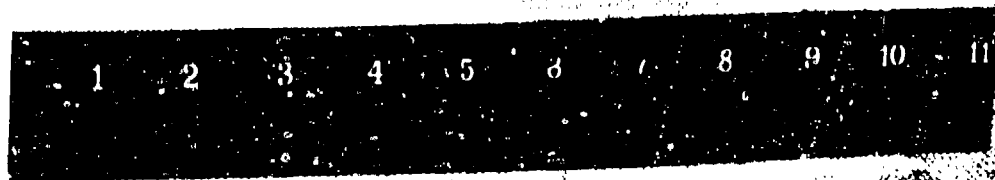


FIGURE 3: IRREGULARITIES AND REPAIRS IN THE INFLATED
WOVEN SECTION



FIGURE 4: NEOPRENE-LATEX APPLICATION BY BRUSH IN THE
CELL-WEB JOINT

these yarns would be satisfactory for fabricating the shelter units.

2.8 Tests of Laboratory-Coated Fabric

- 2.8.1 Tests were conducted on the laboratory-coated fabric to verify that materials and processes selected would meet the requirements set forth in the work statement. Test specimens were evaluated for tensile strength and elongation in warp and fill directions. Tests were conducted to determine the weight of coated fabric, flame resistance, adhesion of coating and adherability.

Samples for the adherability tests were fabricated with polyester fabric coated with olive green material bonded to olive green spray-coated polyester fabric, and pale green coated polyester fabric bonded to the pale green spray-coated polyester fabric. The adherability specimens were made with UBAGRIP Adhesive, N-136 B & A.

- 2.8.2 The fabricated sample was dead load tested (Adherability Tests) for four hours at 70°F and 200°F. In both tests, the applied load was 40 pounds per inch width for 2 inch bond overlap. All samples passed the dead load test at 70°F and 200°F except one which failed after 10 minutes at 200°F. The visual examination of that sample indicated that failure occurred between the fabric and the coating compound and not in the sample bond joint area. It also appeared that there was not sufficient penetration of spray compound on the inner wall of the sprayed surface. Consequently, under load, the separation occurred between the fabric and spray compound.

- 2.8.3 The fabrication of all seam test specimens throughout this development program was accomplished in accordance with LP/P. DES 42-70, paragraph 4.4.1.

Successful tests assured that the materials and fabrication methods would meet the specification requirements for the shelter sections. Therefore, without further changes, these coating materials and the spray-coating methods were used for the fabrication of all three MUST shelter section casings.

3.0 EVALUATION OF SPRAY-COATED, 3-D WOVEN FABRIC SHELTER CASINGS

3.1 Tensioning and Spraying

- 3.1.1 The tensioning of the woven fabric shelter section casings is described in detail in the Manufacturing Methods Report, Ref. 1. However, in order to comprehend the procedures and problems encountered, some details of importance are repeated.

Each uncoated fabric casing had to be deployed into its inflated arch shape and tensioned sufficiently to remove significant wrinkles in order to permit application

of a uniform spray-coating. This was accomplished by installing the uncoated casing in holding fixtures which secure the casing ends in correct position and plug the open ends of the casing cells. Tensioning is then accomplished by inserting the cell inflation bladders surrounded by polyethylene film tubes inside the casing cells and then inflating the bladders. Inflation of the bladders then tensions the casing material in its finished, erected, arch configuration removing wrinkles. The polyethylene tubes are pressed tightly against the inside surfaces of the casing cells preventing excessive penetration of the latex spray while providing a release fill surface so that the bladders and the polyethylene tubes can be removed after drying of spray coat. The low friction polyethylene surface also permits some realignment of bladders for uniform filling of the casing's cells.

- 3.1.2 The installation of the uncoated woven fabric shelter casings in the holding fixtures and the insertion of the polyethylene tube enveloped bladders was not difficult but must be done carefully.

Unequal distribution of a bladder within a cell can induce wrinkling of the casing fabric. As bladder inflation progresses, some realignment of the bladder may be necessary to avoid such wrinkling. After bladder inflation, care should be taken not to displace casing yarns in trying to rub out or work out any remaining casing fabric wrinkles. The casing fabric is a low count plain weave and yarns can be displaced easily leaving large gaps which would be difficult to close by spraying. Equal spacing of yarns should be achieved before spraying.

- 3.1.3 The casing surface should be inspected after each of the first several spray coats for pinholes in repair areas or where yarn gaps exist. A brush coat of the Neoprene-latex coating should be applied over such areas to help the spray coat to web over such hole areas. This should be continued until a hole-free coating surface is achieved. See Figure 4.

- 3.1.4 One coat was sprayed over the section surfaces (inner and outer wall) in less than one half hour with one spray gun and two operators.

- 3.1.5 Neoprene-latex is a water based spray compound which, during high humidity days, required up to two hours drying time between the coats. A high volume fan was constantly running but did not significantly shorten the drying time. A humidity controlled area would have shortened the drying time and the spraying process.

- 3.1.6 The white, A-625-B "Radalon", was sprayed over the dried black Neoprene-latex base coats using standard DeVilbiss spray equipment. No difficulties were encountered during this coating operation or the subsequent operations of spraying two coats of pale green over the white coated inner surfaces and spraying two

coats of olive green over the white coated outer surfaces.

- 3.1.7 Both coated surfaces were inspected for pinholes or other discrepancies. Wherever discrepancies were found, they were corrected by local coating applications.
- 3.1.8 Safety precautions should be observed during the spraying operations.
 - 3.1.8.1 When spraying Neoprene-latex the spray operator should wear a filter respirator and safety goggles; and, since the spray system uses very high pressure, care should be taken in the condition of spray equipment and the integrity of connections.
 - 3.1.8.2 When spraying the "Radalon" coatings, the spray operator should use a full breathing mask; and eye covering should be used since the solvents in these spray solutions are toxic and flammable. Spray area ventilation and fire proofing should be provided.

3.2 Test Results of Spray-Coated Fabric Casing Material

After two days of drying time, a three-foot-wide portion was cut off from one end of a sprayed casing. Part of this coated fabric was sent to Natick Laboratories for their tests. The remaining portion was used for in-house testing.

Table No. 1 shows all other test results, conducted by B.F. Goodrich Company, as required by the contract.

Except for the color, there is no significant difference between the physical properties of outer and inner spray coated woven casing walls.

Copies of the original grab tensile test charts for these materials are shown in the Appendix, pages A-1 through A-4.

3.2.1 Weight of the Coated Casing Fabric

The weight of the 3-Dimensionally woven coated casing fabric, tested per Test Method 5041 of Federal Standard 191, is significantly greater (up to 133%) than the standard shelter wall material, MIL-C-43285B, Type I, Class 1 and 2.

This greater weight is caused by:

- a. Heavier yarns used in weaving.
- b. Heavier thickness of the coating compounds.

The average weight of the spray-coated inner and outer MUST casing wall was 32 to 35 ounces per square yard.

CHARACTERISTIC	TEST METHOD*	REQUIREMENTS MIL-C-43285 B		OLIVE DRAB		PALE GREEN	
		TYPE I CL. 1 & 2		OUTER WALL		INNER WALL	
		MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
Weight, oz./sq. yd.	5041	13.0	15.0	33.5	36.2	30.9	32.0
Breaking Strength	5102	160		320	370	320	370
In Lbs.	F (fill)	160		200	235	200	235
Stiffness Test (cm)							
Original	75°F W		13	13.8	17.2		14.8
	F		13	15.1	16.0		15.6
	W		20	17.6	20.3		18.8
	-40°F F		20	18.5	20.5		19.6
Accelerated	75°F W		20	21.6	23.6		22.7
Weathering**	F		20	23.5	25.4		24.5
200 hours							
Oven Aging***	W	20					
100 hrs. Oven	-40°F F	20					
180°F							
Blocking @ 200°F	5872	No. 2		No Blocking.	Cloth Surfaces Adhere Slightly.		
Flame Resistance	W	3		0	6	1	2
After Flame (Sec.)	F	3		0	4	1	2
Char Length (In.)	W	4.5		1.5	2.1	1.9	2.8
	F	4.5		1.8	2.1	1.5	1.6

* All test methods per Fed. Standard-191.

** Accelerated Weathering per Method 5804, tested per Method 5204. Both methods are per Fed. Standard-191.

*** After: oven aging - Specimen exposed to circulating air oven at 180°F + 20°F for 100 hrs. Tested at -40°F per Method 5204 of Federal Standard-191.

TABLE I - TEST RESULTS ON SPRAY-COATED, 3-D WOVEN CASING FABRIC

3.2.2 Breaking Strength of the Spray Coated Fabrics

As the result of larger yarn diameter, the breaking strength of tested samples was, on the average, 100% higher in the warp direction and 35% higher in the fill direction than the requirements for casing fabric stated in the Specification (MIL-C-43285B).

The samples were tested per Method 5103 of Federal Standard 191.

3.2.3 Stiffness Tests of Spray Coated Fabric

The stiffness tests were conducted per Method 5204 of Federal Standard 191.

3.2.3.1 The original samples tested at 75°F indicated an increased stiffness when compared with MIL-C-43285B casing fabric specifications (14% higher for warp and 20% higher for fill direction).

3.2.3.2 Samples tested at -40°F showed an improvement of 6% for warp and 2% for fill direction, when compared with MIL-C-43285B specification

3.2.3.3 Test samples were exposed to an accelerated weathering per Method 5804 of Federal Standard 191 for 200 hours without filters, then dried, brought to equilibrium under standard conditions, and tested at 75°F per Method 5204 of Federal Standard 191. These samples were stiffer than the specification requirements by 14% in the warp direction and 22% in the fill direction.

3.2.3.4 The oven aged samples were exposed to heat for 100 hours in an air circulating oven at 180 ± 2°F. Prior to testing at -40°F these samples were brought to equilibrium under standard conditions. These samples were too stiff to be tested. When sharply bent, some coat cracking was observed.

This test was repeated twice, and both times the outside wall (olive drab) and inner wall (pale green) samples exhibited the same stiffness and coat cracking.

3.2.3.5 The stiffness encountered in most of the spray-coated Neoprene-latex samples is the result of:

- a. Increased woven fiber diameter.
- b. Increased coating thickness.
- c. The Neoprene-latex coating properties.

3.2.3.6 Test Method 5204 required the testing of samples in the warp direction only. In our tests, samples in both the warp and fill directions were tested in order to determine if differences occurred. Test samples cut in either fill or warp direction curled laterally approaching a tubular shape during the oven aging process making the sample even stiffer and difficult to test at -40°F. The sample curling condition is attributed to the residual tension from inflation stress during the spray-coating process which is locked in by the coating.

3.2.4 Blocking Tests of the Coated Woven Fabric

The effect of temperature on spray coated fabric resistance to blocking was determined by Method 5872 of Federal Standard 191.

All tested samples which were taken from outer or inner casing wall surfaces passed the test (Scale 2 - No Blocking, cloth surfaces adhered slightly).

3.2.5 Flame Resistance of Coated Woven Fabric

The samples were tested per Method 5903 of Federal Standard 191.

3.2.5.1 The after-flame burning time of most tested samples fell within the specification requirements. Several samples of the outer wall which did not pass the test had 4 and 6 seconds after-flame time. Visual inspection of these samples revealed exposed dipped polyester yarn on the inside surface of the sprayed walls. This condition was the result of the inability to completely cover the fabric with latex on the inside surface of the casing cells by external spray application. The exposed dipped polyester yarn appears to sustain after-flame time.

3.2.6 Char Length of the Spray Coated Fabric

3.2.6.1 All samples fell well within test specification requirements for char length.

3.3 Fabric Test Results Compiled By Natick Laboratories

The test results of tear strength, hydrostatic resistance, and adhesion to coating are shown in Table No. II. Those tests were performed by Natick Laboratories on spray coated samples cut from the first spray coated casing.

3.3.1 From this table it can be concluded that the sample tear strength far surpassed the MIL-C-43285B requirements (up to 600%).

3.3.2 The adhesion to coating of the dry and most of the wet samples appear to be satisfactory - above the MIL-C-43285B requirements. Some wet samples, for an unknown reason, did not meet these requirements.

Characteristic	Test Method 1/	Requirement MIL-C-43285B (1) Type I Class 1 & 2		OD Face/ Black Back 2/		Pale Green Face/ Black Back 2/	
		Min.	Max.	Low	High	Ave.	Ave.
Weight, oz./yd.	5041	13.0	15.0	28.3	32.5	30.4	33.3
Breaking Strength Lbs.	5102 W	160	-	195	280	255	328
	5102 F	160	-	155	200	176	161
Tear Strength, grams	5132 W	3500	-	24000	3/	21000	22300 3/
	5132 F	3000	-	17000	23000 20000 3/	24000	24000 3/
Hydrostatic Resistance, PSIG	5512	300	-	75	550	310 4/	512 4/
Adhesion of Coating, Lbs /2 in width 5/	5970 Dry	16	-	14.5	23.0	18.8 7/	23.2 29.0 25.1 7/
	5970 6/ Wet	12	-	11.1	22.3	16.7 7/	6.5 16.2 11.4 7/
Stiffness, cm	5204 @ 70°F	-	13.0	15.8	17.5	16.7 3/	17.7 18.1 17.8 8/
	5204 @ 40°F	-	20.0		3/ 8/		3/ 8/

a/ FED-STD-191 e/ Face or more heavily coated side of the cloth.

b/ Warp yarns were assumed to be perpendicular to the lengthwise direction of the webbing. f/ After 24 hours of being immersed in distilled water at room temperature.

c/ Only 3 specimens were tested. g/ Only 2 specimens were tested.

d/ Only 4 specimens were tested. h/ No result: specimens were too stiff to test-cracking or coating was observed when specimens were folded sharply.

TABLE II: NATICK LABORATORY TEST RESULTS ON SPRAY-COATED 3-D WOVEN FABRIC MUST SHELTER CASING MATERIAL

3.3.3 The hydrostatic resistance of tested samples appears to be good - probably because of the coating thickness of spray coated fabric.

3.3.4 Table II also shows test results of breaking strength, stiffness, and weight. These results, obtained by Natick Laboratories, correspond very closely to the results obtained in our laboratory tests.

3.4 Adherability Tests of Spray-Coated Woven Fabric Casing

During assembly of the shelter section, it is necessary to adhesive bond chloroprene rubber coated fabrics to the spray-coated casing fabric. Adherability tests were conducted throughout this development program to assure the quality of such bonded attachments.

The outer surface of the spray-coated casing fabric must be adhesive bonded to the black chloroprene coated surface of MIL-C-43285B, Type I, Class 1 coated fabric.

The inner surface of the spray-coated casing fabric must be adhesive bonded to the black chloroprene coated surface of MIL-C-43285B, Type I, Class 2 coated fabric.

Samples of adhesive bonds of these material combinations were fabricated and tested for each of the three shelter section casings which were spray coated during this program.

These adherability tests were conducted in conformity with the requirements of MIL-C-43285B, paragraph 4.4.5 and LP/P. DES 42-70, paragraph 4.4.

3.4.1 Adherability Tests of the First Spray-Coated Casing

3.4.1.1 As stated earlier in this report, it was decided on the basis of tests of bonds using preliminary spray-coated material to use UBAGRIP N-136 B & A adhesive for such bonds. Samples from the first spray-coated casing were fabricated using that adhesive.

3.4.1.1.1 The fabricated lap seam samples were dead load tested for adhesive strength at 75°F and 65% relative humidity for four hours. The applied load was 40 pounds per inch of width. The bond lap was 2 inches.

Samples of both inner and outer casing surfaces fabric passed this test. There was no visible slippage of the bonded seams.

3.4.1.1.2 The same samples were then tested in an air circulating oven at 200°F, under a load of 40 pounds per inch. After five minutes in the oven, all samples failed. After removal from the oven and cooling to room temperature, the failed sample seam adhesive appeared to be tacky to the touch. One day later the adhesive exhibited the same tackiness.

3.4.1.2 Because of these failures, two new sets of test samples were made. One using the same UBAGRIP N-136 B & A adhesive, and the other using Bostik 1039 adhesive with Boscodur No. 5 curing agent. After seven days of adhesive bond cure at room temperature, these samples were dead load tested.

3.4.1.2.1 Both sets of samples passed the dead load adhesive strength test of 40 pounds per inch at 75°F and 65% relative humidity for four hours.

3.4.1.2.2 The UBAGRIP N-136 B & A adhesive test samples failed the dead load test at 200°F temperature. The failure of all five (5) samples occurred within ten minutes. When visually inspected, they exhibited the same adhesive tackiness to the touch as the first samples.

3.4.1.2.3 The samples bonded with Bostik 1039 and Boscodur #5 passed the dead load test at 200°F for four hours. There was no visible bond slippage.

3.4.1.3 Because of the failure of two separate sets of UBAGRIP N-136 B & A adhesive test samples at 200°F and the success of Bostik adhesive, it was decided that adhesive bonds would henceforth utilize Bostik 1039 and Boscodur No. 5 mixed in the ratio 16:1 parts by volume.

The change over from UBAGRIP to Bostik adhesive was effective on May 21, 1975.

3.4.1.3.1 The following parts were bonded with UBAGRIP N-136 B & A adhesive:

- a. Both end panels.
- b. All reinforcements on the first sprayed casing except the sectionalizing straps and the 31-foot-long slide fasteners used for attachment of end panels to the sections.
- c. All bladders.

In spite of being bonded with UBAGRIP adhesive, the above parts should sustain test temperatures to 160°F.

3.4.2 Adherability Tests of the Second Spray-Coated Casing

A new set of adherability samples was fabricated from the second spray-coated casing.

3.4.2.1 All test samples passed the room temperature dead load (40#) adhesive strength test for four hours at 75°F and 65% relative humidity.

3.4.2.2 The same samples were then dead load tested in a circulating air oven at 200°F. Two of the test samples failed. The remaining three passed the test.

Visual inspection of the failed samples revealed that the failures occurred between the casing fabric and the Neoprene-latex. There was no indication of any slippage of the adhesive bond in the samples that passed the test nor in the samples that failed. No significant difference in appearance between the material of the first and second casings was observed.

Investigation of the spraying techniques did not reveal significant difference in process to which reduced coat adhesion could be attributed.

Further investigation did indicate two factors which could contribute to reduced coat adhesion. These were:

- a. The first casing had approximately seven days more drying time after spraying before sample preparation.
- b. The second casing was approximately three weeks older than the first casing at the start of the spraying operation so that the dip coat on the yarn would have aged an additional three weeks.

3.4.3 Adherability Tests of the Third Spray-Coated Casing

By the time the test samples of the second casing were fabricated, tested, and the test results analyzed, the third casing was completely spray-coated using the same procedure as for the preceding two. Therefore, it was too late to undertake any change for an improved spraying procedure which could possibly give us better sprayed surfaces.

3.4.3.1 All adherability test samples of the third casing passed the ambient temperature dead load test. When tested at elevated temperature of 200°F, not all samples passed the test. Some of them failed at 150°F exhibiting the same failure mode as described for the test samples of the second casing.

3.4.3.2 This test was repeated several times. Not one of the samples failed at room temperature when tested for dead load adhesive strength. However, the samples failed inconsistently at elevated temperatures between 150° and 200°F. Whenever failure occurred, it was always between the fabric and spray-coating. Not one of the samples failed in the adhesive bond.

3.4.3.3 In addition to the preceding tested samples, six sets of adherability test samples were fabricated from the third casing and stored.

These samples will be tested at the later date in order to determine if adhesive bond strength deterioration or spray-coating adhesion improvement occurs after prolonged aging.

The results of these tests will be reported to the Natick Laboratories in January, 1976.

3.4.4 As the result of the adherability tests, it can be concluded:

- a. The adhesive, Bostik 1039 and Boscodur No. 5 curing agent is compatible with the spray-coating at room temperature and also at the elevated temperature of 200°F.
- b. The failure, if it occurs, will be between the fabric and the spray-coating at elevated temperatures.

3.5 Casing Fabric Yarn Treatment

The yarn supplier selected by Woven Structures, Inc. was not able to provide the desired yarn surface treatment (dip) to enhance fabric-to-Neoprene-latex adhesion. He furnished a yarn dip treatment of an aqueous suspension of isocyanate instead of the desired dip in a solvent solution of isocyanate followed by a dip in resorcinol formaldehyde latex (RFL) solution.

As a result of the aqueous yarn finish provided, a relatively heavy cohesively bonded coat was applied to the yarn, effectively sealing the yarn against penetration among the yarn filaments by the spray-on latex. This reduced mechanical adhesion of the spray-coating.

The aqueous suspension applied yarn finish apparently did not cross-link with the spray-coating so that no chemical bond was achieved.

The aqueous yarn finish also stiffened the yarn making it difficult to loom.

- 3.5.1 Spray-coating adhesion to the 3-D casing fabric can probably be improved by improved cord treatment systems and better age control from yarn dipping to spray-coating.

3.6 Fabrication and Evaluation of the End Panels

The MUST unit end panels were fabricated per U.S. Army Natick Laboratories Drawing No. 5 - 4-1373 and the specification LP/P. DES 42-70 of September 1, 1970.

All the materials and associated hardware except for the adhesive were in accordance with the specification.

As previously stated, Staley Adhesive, N-136 B & A was used throughout the end panel fabrication. The dead load adhesive strength test samples utilizing specified materials passed the room temperature and the elevated temperature tests for four hours at 200°F under load of 40 pounds/inch. No other tests were conducted on these materials since they are specified for the fabrication of the conventional MUST shelters and not subject to development effort in this program.

The end panels were completed before May 21, 1975 when the Staley Adhesive was replaced by the USM Bostik 1039 and Boscodur No. 5 adhesive.

The end panel construction was routine fabrication and assembly of specified materials per existing drawings under standard quality control surveillance of materials and workmanship.

3.7 Fabrication and Evaluation of Bladders

The bladders were fabricated of polychloroprene coated nylon fabric purchased to specification MIL-C-19002C, Type I, normally used for pneumatic life preserves. This material was coated on one side and had very good air retention characteristics. It did not block at 200°F and had good low and high temperature resistance to cracking, flaking, and coat separation.

- 3.7.1 Each bladder was fabricated by adhesive bonded seaming of 13 segments per B.F. Goodrich Drawing 5X2101 and 5X2113. Each bladder's total length and its end closure were the same as for the standard shelter bladders.

- 3.7.2 Because the 3-D woven casing sections' two outermost cells were larger in diameter than the ten in between cells, it was necessary to fabricate two diameter-sized bladders. The larger bladders (for the outermost cells) were 64" in circumference and were made of orange colored coated fabric, while the in between bladders were 58.5" in circumference and were gray in color.

- 3.7.3 A four-foot-long bladder section (Figure 5) was fabricated and tested for its air retention at room temperature and in the hot air oven at 160°F. During the room temperature tests, there was no visible air loss demonstrating that the air retention of bladder material was good.

Also, there was no seam failure during the bladder's elevated temperature test showing that the Adhesive N-136 B & A is compatible with the polychloroprene coating.

- 3.7.4 All bladders were fabricated or were in the process of fabrication by May 21, 1975 when the Staley Adhesive N-136 B & A was replaced with the USM Bostik 1039 and Boscodur No. 5 adhesive. Therefore, all bladders were completed with N-136 B & A adhesive. However, B.F. Goodrich Drawings 5X2101 and 5X2113 indicate that, for future fabrication, Bostik 1039 adhesive should be used.

- 3.7.5 Upon completion, but prior to check valve installation, each bladder was inflation tested for 24 hours for its air retention. All bladders tested within the specification requirements.

3.8 Testing of Check Valves

Each check valve was air-leak tested in accordance with the requirements of U.S. Army Natick Laboratory Drawing No. 5 - 4-1399. Figure No. 6 shows the valve leak test apparatus in use.

- 3.8.1 The valve test apparatus consisted of a pressure container 1,400 cubic inches in volume to which each valve was mounted and individually tested. A hose connected the pressurized container to manometer. The container pressure was set at 27.7 inches of water. The valve is considered acceptable if its leakage does not permit the container pressure to fall below 22.7 inches of water in 10 minutes. This acceptable leak rate corresponds to 25 cubic centimeters per minute as stated on Natick Laboratory Drawing 5-4-1399. The calculations affirming this equality are in the Appendix of this report.

- 3.8.2 Several valves had to be rejected because of excessive leakage rate.

- 3.8.3 The tested valves were then installed in bladders and leakage rechecked by inflating the bladders to 1.5 psi. To be acceptable, bladder pressure must not fall below 0.2 psi in 24 hours.

All bladders with valves installed passed this leakage test.

3.9 Testing and Evaluation of Pressure Relief Valves

The pressure relief valves (Bridgeport Brass Co., Part No. 724.5) for bladder mounting should open at a pressure of 1.5 psi or slightly higher. Several valves



FIGURE 5: BLADDER TEST SECTION - FOUR FOOT LENGTH

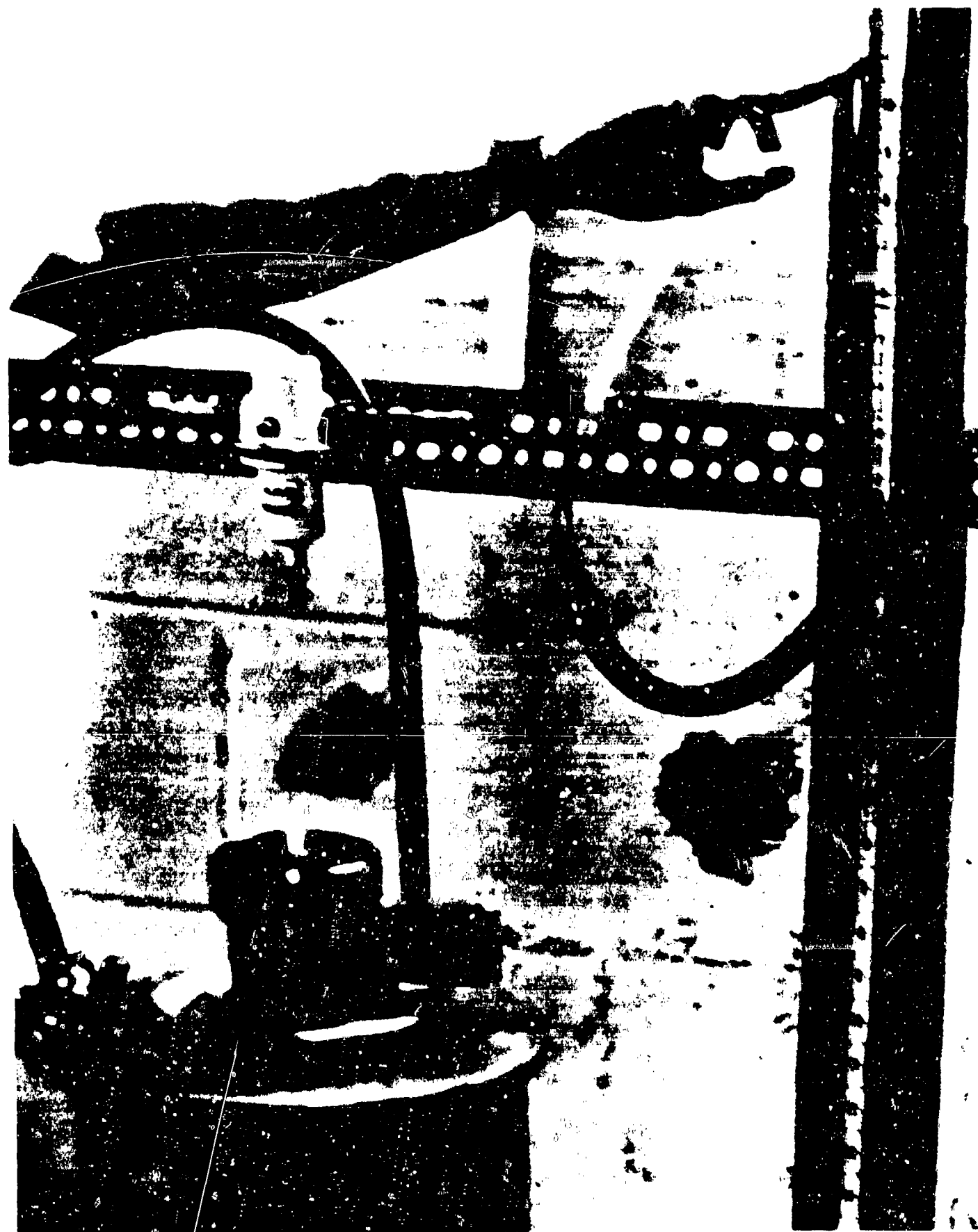


FIGURE 6: LEAK TESTING OF CHECK VALVES

were tested and it was found that their opening pressure range varied from 1.3 to 2.5 psi although all valves had identical actuating springs. This Bridgeport Brass Company valve spring has a tendency to stick inside its housing affecting the opening pressure.

- 3.9.1 Two sets of pressure relief valves were provided with the three shelter units delivered. The valves mounted in the bladders were selected for opening pressure of 1.5 to 1.75 psi. A second, unmounted, set of 36 valves selected for opening pressure of 2.00 to 2.5 psi was provided for use during the overpressure test of the shelter sections.

4.0 ASSEMBLY OF SHELTER SECTIONS AND SHELTER UNIT

Most of the shelter unit subassemblies were not affected by this development program. These were fabricated in accordance with existing specifications. Only those subassemblies and assemblies which were newly developed or changed to accommodate the new developments are discussed in this section.

4.1 Spray-Coated Casing Assembly

After completion of the casing spray-coating operations and while the casing is still inflated in the spray holding fixture, it is necessary to locate and mark on the casing the positions for all attachments to the casing and the end cut-off lines for the casing.

- 4.1.1 Initially, all radial layout locations were marked on the floor for transfer to the casing after spraying by a plumb bob and line. It was found, however, that the casing arch did not exhibit a true radius over its entire span and this method of location was unreliable.
- 4.1.2 A longitudinal centerline was worked on the casing midway between the spray holding fixture ends and all radial layouts were measured from this longitudinal centerline on the inner and outer casing surfaces. Layout locations in the axial direction were all measured from the internal webs of the front and rear casing cells.
- 4.1.3 Bonded-on attachments to the casing surfaces should be applied while the casing is inflated, either in the spray holding fixture or during a subsequent inflation after the casing ends have been closed and the bladders inserted. Normally, the end panel slide fasteners and the sectionalizing straps would also be bonded on at that time, but during this program these latter two attachments were not attached until the sections had been otherwise assembled and erected for joining, anticipating a need for relocation of the slide fasteners and straps.
- 4.1.3.1 Before the casing ends are closed by sewing on end closure panels, the bladder

insertion zippers, the check valve clearance and mounting holes, and the pressure relief valve clearance hole inserts should be attached as detailed in the Manufacturing Methods Report, Reference 1.

4.2 Inflation Bladder Insertion

The installation of bladders into the casing cells was accomplished by pulling with 40-foot-long ropes which were fed through the zipper openings of each casing cell. The bladders were attached to the rope. The ropes were pulled through the section cells. During this operation, it was important to prevent rotation of the bladders within the cells. The direction of bladder curvature must coincide with the casing curvature.

4.2.1 The bladder check valves are attached to their mountings on the casing and the pressure relief valves are inserted through the casing clearance holes. The inflation manifold is attached to the check valves for section inflation.

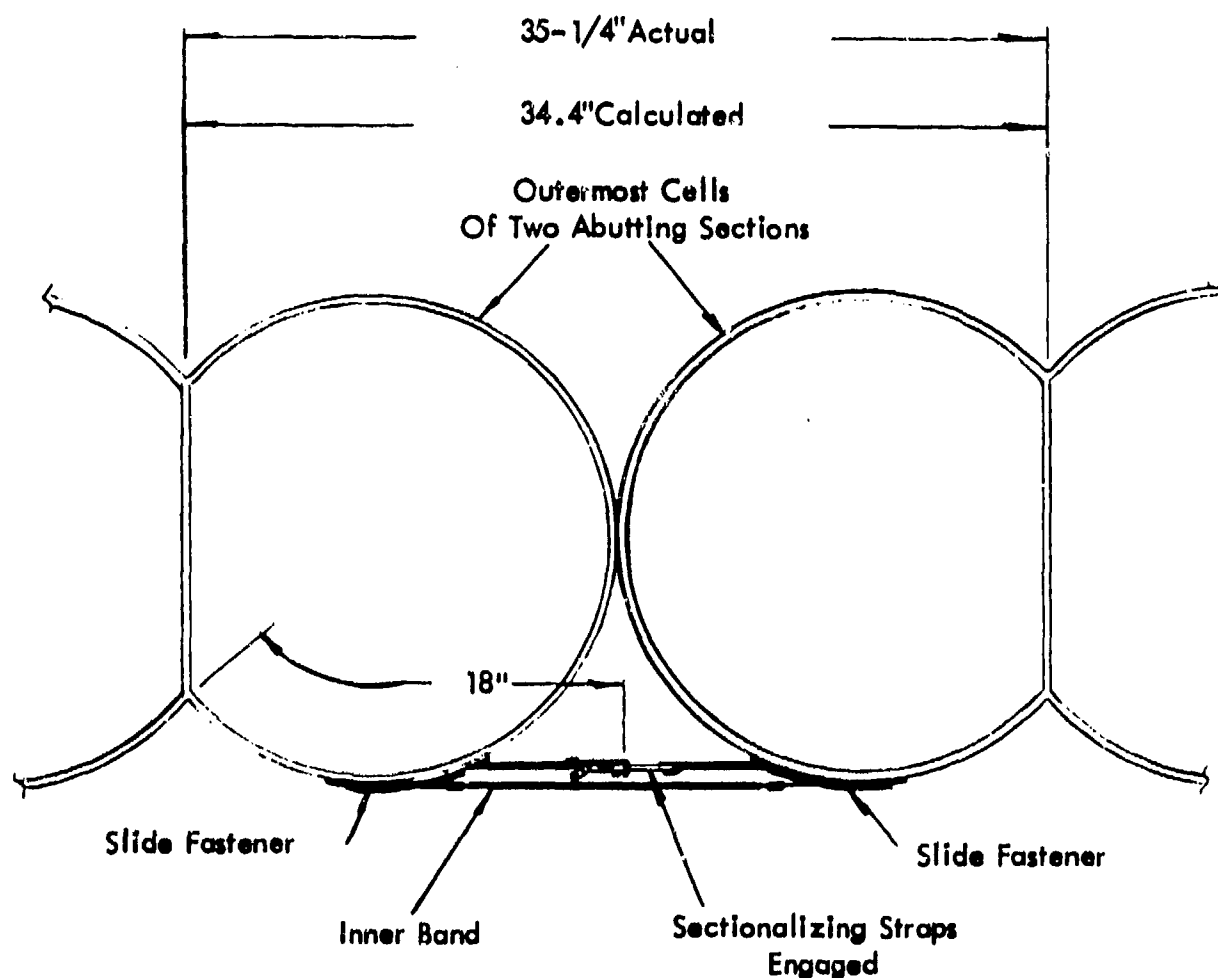
4.2.2 Upon first inflation, some wrinkles appeared at the top of the inflated section, which were the result of an uneven distribution of the bladders within the cells. To correct this condition, it was necessary to redistribute the bladders in some cells.

The best method found to distribute the bladders within the cells, was with the use of a 16-foot-long ridge pole. The pole was positioned under the casing after the bladders were inserted. By lifting the overhanging ends of the pole, the casing center was raised and the bladders were deployed lengthwise. The section was then inflated. The decreased friction of the hanging bladders (the bladder surfaces are not entirely in contact with the section walls) permits sliding of the bladders within the section cells. With this method of inflation, we obtained almost wrinkle free outer and inner surfaces in the inflated section. Once the bladders were properly located, deflation and reinflation did not appreciably change the bladder position.

4.2.3 Location and Attachment of Sectionalizing Straps

In production, the sectionalizing straps would have been located and bonded to the casing surface at the same time as the other attachments and hardware. However, since we did not know the exact fit of the sections in an assembled shelter unit, we decided to locate and attach these straps in place at assembly.

To accomplish this operation, two shelter sections were inflated to 1-1/2 psi air pressure and placed end to end. The distance between the end cell webs of the two abutting sections was measured and compared with the calculated dimensions. The measured dimensions was larger by 7/8". This increase of 7/8" can be attributed to casing growth due to inflation stress and to the slight difference in diameter of two abutting outer cells from standard casing cell size. See sketch on the next page.



The third shelter section was inflated and the three sections were abutted in all possible combinations measuring the distance between webs in abutting sections. Sections should be capable of interchangeability.

The sectionalizing straps were then sized and located to hold the sections intimately in contact with each other with small compression. Appropriate drawing changes were made to reflect strap length and location. The straps were then fabricated and attached.

4.2.4

Location and Attachment of Slide Fasteners

Because the outermost cells of the 3-D woven casings were larger in diameter than the in between cells, particular attention had to be given to the location of separating type slide fasteners. These slide fasteners are used for attachment of end panel assemblies and for joining abutting sections via the inner band which had mating slide fastener halves.

The front and rear end panel assemblies were positioned under the end cells of the inflated shelter sections and a slide fastener location was determined which permitted interchangeable end panel assemblies onto any of the three shelter sections. Appropriate drawing changes were made to describe the slide fastener attachment.

4.2.4.1 Since access to the inside of the casing end cells was not possible because of the integral 3-D woven construction, the slide fasteners were sewed to a coated fabric attachment strip for adhesive bonded attachment rather than sewing directly to the casing.

4.2.4.2 Because of the greater diameter of the casing end cells (compared to former casing design), the end panels had to be located two inches outboard of their former position causing a change in inner band width and floor assembly length.

4.2.5 Redesign and Attachment of Inner Bands

As explained in the preceding paragraph, relocation of the slide fasteners necessitated redesign of the inner bands by making them of an appropriate narrower width. Appropriate drawing changes were made and the bands fabricated and installed.

4.2.6 Redesign of Floor Section Assemblies

Because of the need to locate the slide fasteners two inches farther outboard on all shelter sections, as explained in paragraph 4.1.4.2, the floor sections, which had already been fabricated to specification dimensions, were four inches short in each shelter section. Drawing changes were made to reflect four inch longer floor panels.

4.2.6.1 The floor sections which had already been fabricated were not changed, but a 12-inch-long special floor panel insert was fabricated to make up the accumulated floor assembly shortage of all three shelter sections which joined into one continuous unit.

4.2.7 Weather Seal Redesign and Attachment

The weather seals which overlay the abutting end cells of abutting shelter sections were redesigned to accommodate the larger dimension end cells. Appropriate drawing changes were made and the weather seals fabricated and assembled for fit check.

4.2.8 Miscellaneous Subassembly Redesign

In order to accommodate the slightly different dimensions of the 3-D woven casing unit or to provide more adhesive bonding surface where sewing could be performed in some areas of the integrally woven casing, minor changes were made in the design of several subassemblies not discussed in detail. These include:

- a. Plenum - Section Assembly
- b. Guy Rope Patch Assembly - Section Assembly
- c. Closure - Arch to Sod Cloth - Section Assembly
- d. Closure - Arch to Ground Cloth - Section Assembly
- e. Ground Cloth - Section Assembly
- f. Sod Cloth - Section Assembly
- g. Floor Transition - Shelter Assembly

The new designs and applicable drawings are referenced on B.F. Goodrich Drawings 4X2139, "Master Drawing List - MUST Shelter" and 5X2097, "Inflatable Shelter Assembly - MUST" and its referenced subassembly and detail drawings.

4.2.9 Assembly of Shelter Sections

Erection and assembly of the components previously described completes the Three-Section MUST Shelter.

5.0 INSPECTION AND QUALITY CONTROL

The Quality Assurance Program, as presently established at the B.F. Goodrich Engineered Systems Company, is in accordance with the requirements of MIL-Q-9858A. All materials used in the fabrication of the MUST Shelter Unit were subject to quality control beginning with the receiving of raw materials and continued throughout the manufacturing process and end item inspection.

5.1 Receiving Inspection of Materials

All materials purchased from outside vendors are subject to receiving inspection to assure conformance with procurement specifications.

5.1.1 Standard Hardware and Components

All standard hardware and components procured to customer drawings or specifications are inspected upon receipt to assure that there has been no visible damage during shipment, that specified quantities are provided, that certificates of conformance and test results are received with the materials where applicable, and that procurement specifications have otherwise been satisfied.

Coated fabric purchased to military specifications and accompanied by test results and/or certificates of conformance are visually inspected for local surface defects.

5.1.2 Spray-Coating Materials

The spray-coating compounds used for coating the 3-D woven fabric casings in this program were provided by the Latex and Adhesives departments of B.F. Goodrich General Products Company, a corporate division. They were selected to satisfy the requirements of this coating application and, in the case of the "Radalon" coatings, were specially pigmented to provide the specified colors.

These coatings are mixed in accordance with established specifications and tested for significant properties by their manufacturing departments.

5.1.3 Woven 3-D Fabric Casings

These casings were developed during the performance of this program using weaving techniques proprietary to Woven Structures Company. The achievable quality for such fabric casings was not known at the start of the program since some process development was included. There were, therefore, no established quality standards other than the knowledge that the casing strength should be at least equivalent to that of the coated fabric sheet conventionally used for casing fabrication.

Some defects were present in all of the casings in their as-woven condition. These were repaired by hand reweaving. The quality of the casings, or at least the freedom from defects, noticeably improved as weaving experience was gained.

Dimensions of the woven 3-D casings are shown on Table III. These dimensions were supplied by Woven Structures Company.

5.2 In-Process Inspection

A number of precautions, checks, or inspection points should be observed during the fabrication process or in storing or handling of materials. These should be checked by a quality control inspector or observed by responsible production personnel.

A number of subassemblies were fabricated to established specifications. In-process inspection of these are not discussed.

5.2.1 3-D Woven Fabric Casings

Casings should be inspected for weaving quality, freedom from unrepaired defects, yarn dip coverage and age, and dimensions.

	<u>Part 1</u>	<u>Part 2</u>	<u>Part 3</u>
Length of Part (measured along inner face)	39' 0"	37' 10"	38' 9"
Weight of Part	91 lb	88.5 lb	89.5 lb
Fabric Width, Not Including Tabs	162"	161"	161"
Cell Height	16"	15 3/4"	15 3/4"
Center Cell Width, Measured at Outer Face	13"	13"	13"
Center Cell Width, Measured at Inner Face	13"	13"	13"
End Cell Width, Measured at Outer Face	16"	15 3/4"	16"
End Cell Width, Measured at Inner Face	16"	15 3/4"	15 3/4"
Warp & Fill Count, Outer Face	22 1/2 x 22 1/2	22 x 22 1/2	22 1/2 x 22 1/2
Warp & Fill Count, Inner Face	23 x 27	22 1/2 x 27	22 1/2 x 27
Warp & Fill Count, Lock Area, Inner Face	45 x 53	44 x 53	42 x 53
Warp & Fill Count, Lock Area, Outer Face	44 x 44	44 x 44	44 x 44

TABLE III: 3-D CASING FABRIC DIMENSIONS, AS WOVEN.

- 5.2.1.1 Weaving defects which would locally weaken the structure should be rewoven. As weaving experience is gained, the number of weaving defects should decrease and a standard for classifying the criticality of defects and the acceptable limits on the number and size of repairs should be developed.
- 5.2.1.2 Casing dimensions should be checked to assure that there is at least one foot of casing length at each end of the casing arch in excess of finished length in order to provide enough material for mounting in the spray-holding fixtures and to provide some material for test samples. Individual cell widths and internal web lengths should be checked to insure compatibility with bladders and finished part interchangeability.
- 5.2.1.3 Yarn or fabric surface treatments (dips) intended to enhance elastomer coating adhesion tend to be age sensitive; i.e., they lose effectiveness with time. Every effort should be made to minimize the time lapse between surface coating and yarn treatment.
- Further development of yarn or fabric treatment systems should be undertaken, in an attempt to improve coating elastomer to fabric adhesion. Other yarn suppliers may be able to provide the desired yarn treatments. It may be possible to spray-coat the casing with a final surface treatment to replace or reactivate yarn coatings which must have aged in storage, weaving, or shipment.
- The casing can be visually inspected for color uniformity of dip coatings, and coat adhesion should be checked by testing samples made from coated edge trimmings from each casing.
- 5.2.1.4 After installation in the holding fixture for spraying and after inflation of bladders, the casing arch should be inspected for freedom from surface wrinkles, sufficient length of arch between holding fixtures, inflation pressure, installation to layout lines.
- 5.2.1.4.1 Bladders should be inserted and inflated first in a center cell (as shown in Figure 7) with the remaining cells inflated from this center cell outward one by one for wrinkles minimization.
- 5.2.1.5 The casing weaver can provide "indicator" lines for finished casing cutoff and spray-holding fixture edge alignment by weaving in contrasting color pick yarns at the appropriate positions. These would eliminate the effects of variance in tension, wrinkling, skewing, etc. which could affect the accuracy of measured layouts after removal from the loom.
- 5.2.2 Spray-Coating Materials
- Spray-coating materials include curing agents and tend to be moderately heat-sensitive and age-sensitive. These materials should be procured in accordance



FIGURE 7: INFLATION OF THE SUPPORTED WOVEN FABRIC CENTER CELL

with a schedule that insures usage before excessive aging and should be stored and shipped at moderate temperatures 40°F to 80°F to prevent freezing or heat activation of curing agents.

5.2.2.1 The Neoprene-latex, BFG No. 190X-63112A, should be used within 90 days after mixing for best results. Material to be used after 30 days should be checked for Ph. If the Ph drops below 10.0, the vendor should be contacted for corrective action before use.

5.2.2.2 The "Radalon" coatings should not be stored over 12 months before use, and six months would be a safer shelf life. Application should be in accordance with BFG Industrial Adhesive Products Brochure 2720 on the "Radalon" Coating Series, except that it is recommended that this material be applied "undiluted" to increase coat thickness and to minimize solvent evaporation quantity. A copy of the 2720 brochure is included in the Appendix of this report.

5.2.3 Neoprene-Latex Spray-Coat Application

Eight spray-coats of Neoprene-latex were applied to the casings. Each coating contributes approximately 0.002 inch of thickness for an overall Neoprene coat thickness of approximately 0.016 inch.

After each spray coat, the surface is visually inspected for:

- a) Uniformity of coating coverage.
- b) Pinholes at large openings in the weave.
- c) Runs of coating.
- d) Protruding yarn filaments.
- e) Tackiness before next coat application.

5.2.3.1 Areas exhibiting insufficient coating should be resprayed or brush coated.

5.2.3.2 Pinholes should be filled or webbed over by supplemental brush coating with Neoprene-latex.

5.2.3.3 Runs in the coating should be spread out by brushing while still liquid.

5.2.3.4 Occasionally a yarn end will protrude from the surface, particularly in rewoven repair areas. After the initial spray coating, these yarns are accentuated and more visible. Such yarn ends should be carefully scissor-cut back even with the fabric surface so that successive coats will cover them.

5.2.3.5 Before application of the next coat, the surface should be inspected for the degree of drying accomplished as exhibited by "tackiness". If successive coats are applied too soon, the last applied coat tends to be dissolved by the fresh coat, and runs in the coating occur.

Drying between coats required from 45 to 120 minutes depending on temperature and humidity conditions.

When a spray coat has lost its "tack" or "stickiness" as evidenced by failure to stick to a clean knuckle of the finger lightly touched to the surface, sufficient drying has taken place to start the next spray coat.

The entire casing should be allowed to dry 48 hours after the final Neoprene-latex coat before application of the first Radalon coat.

5.2.4 Radalon Spray-Coat Application

The Radalon spray-coat is applied in two steps: first a base coat of white, then two colored surface coats (light green for inside surfaces and olive green for outside surfaces). These coats should be inspected for coverage and uniformity after each coat. Lightly coated areas should be resprayed.

This material dries rapidly (approx. 15 minutes) and the next coat can be applied immediately after inspection unless retouching was necessary.

5.2.5 Layout On Spray-Coated Casing

After application of the last Radalon coats and while still inflated in the spray fixture, layout lines should be marked on the casing for end cut-off and attachments. Even though indicator threads are provided, the inflated arch length should be checked in marking the cut off lines. Attachment layout could be from surface templates. All layouts should be checked because removal of a mislocated attachment or too short a cut-off may be difficult to repair.

5.2.5.1 After checking of layouts the casing inflation bladders can be removed. The polyethylene film sleeve surrounding the bladders should make bladder removal easy. Removal of the polyethylene film was done by tying the end of the poly to the end of the bladder at one cell end, then sliding the opposite end of the bladder out, which inverts and peels out the poly sleeve as the bladder is withdrawn.

Attachments to the casing should be bonded on while the casing is inflated, either in the spray fixture or in a consequent inflation.

5.2.6 Subassembly Inspection

Fabricated subassemblies should be inspected for appearance, workmanship, and conformance with subassembly drawings and LP/P. Des 42-70.

After subassembly inspection, the shelter sections can be erected and assembled for assembly inspection and acceptance testing.

5.2.7 Final Assembly Inspection and Testing

The final shelter Section Assemblies should be inspected for appearance and workmanship and tested in accordance with the requirements of LP/P. DES 42-70 and the new dimensions associated with this development indicated on the drawings on the revised drawing list, BFG Drawing 4X2139, shown in reduced form in Figure 10 following.

6.0 CONCLUSION AND RECOMMENDATIONS

The objectives of this development program have been accomplished with the delivery of an acceptable MUST shelter unit consisting of three assembled sections, with end panels and other required component subassemblies. Each shelter section had, as its primary structural element, an inflated arch-shaped casing consisting of twelve abutting arched tubular cells. Each cell is individually inflated by an internal bladder fabricated of elastomer coated fabric and pressurized via a check valve and manifold from a common inflation source. Each twelve-cell casing is an integrally woven three-dimensional fabric structure coated on all its outer surfaces by a weather resistant sprayed-on elastomeric coating which also serves as an attachment surface for adhesive-bonded components.

This development program made use of subassemblies and components which are standard to previously procured MUST shelter units insofar as possible, making only those changes needed to accommodate the 3-D fabric shelter sections casing which were the primary effort in this program.

During the performance of this program, further improvements on weaving, processing and fabrication techniques were recognized which could be considered for future development but were not evaluated because of time or budget limitations. These are discussed in the recommendations section of this report, 6.2, following.

6.1 Conclusions

The primary accomplishments of the program are summarized in the following conclusions.

- 6.1.1 The feasibility of weaving full-width double wall with integral webs (3-D fabric) was demonstrated by the principal program subcontractor, Woven Structures, Co. in a new application of their proprietary process. Quality of these 3-D fabric casings improved with experience and several possible further improvements were suggested but not investigated because of program limitations.

- 6.1.2 A suitable system of elastomeric coatings for spray-on application was selected for coating the 3-D fabric casings. Further improvement by providing a cross-linking yarn or fabric treatment seems possible.
- 6.1.3 A system for deploying the 3-D fabric casing into its erected arch shape by means of cell inflation in specially designed holding fixture was devised. This system rigidizes the uncoated casing, eliminates most wrinkles, and stresses the casing nearly the same as in its use condition so that the spray-coating is not subject to stress and delamination from the fabric in the erected mode.
- 6.1.4 Suitable spray equipment for applying the elastomeric coatings was selected or developed and the application technique was described.
- 6.1.5 Redesign of shelter module component subassemblies was accomplished to accommodate small dimensional differences in the 3-D fabric casing as compared to standard subassemblies. The primary dimensional difference was caused by a slightly larger diameter exhibited by the front and rear cells of the section module casing. This larger size was dictated by casing fabric weaving limitations. This larger diameter required location of slide fasteners two inches forward and to the rear of their former locations causing an increase in module length. This, in turn, requires longer plenums, floors, closures, ground cloths, sod cloths, and floor transitions and changes in the width of the weather seals and inner bands and length modification of sectionalizing straps.
- 6.1.6 New assembly, subassembly, and component drawings were made where changes were effective and a new drawing list including these drawings was prepared. BFG Drawing 4X2139. (See Figure 8.)
- 6.1.7 The developed shelter module casing sections exhibit much greater tensile and tear strength than the former casings fabricated from seamed yard goods. The new casings eliminate most structural seams or seals which would weaken at elevated use temperatures.
- 6.1.8 The weight of each section module assembly using a spray-coated 3-D fabric casing is approximately 150 pounds heavier than were the former modules.
- 6.1.9 The cost of fabricating section modules utilizing the spray-coated 3-D fabric casings was estimated to be greater than former modules by approximately \$1500 per module without tooling or \$1750 per module with tooling amortized for a quantity of 1000 modules produced at a rate of at least 100 modules per year. (Reference 1, Manufacturing Methods Report.)

Some additional cost advantages could probably be realized if production rates and quantities justified additional automation of fabrication processes.

6.2 Recommendations

- 6.2.1 Woven Structures, Inc. recommends the use of a modified shuttleless loom with special draw rolls, and conventional harnesses for weaving the arched fabric structure.

This new equipment would be far less complicated to program and would produce the woven fabric with greater accuracy and uniformity. Most of the maintenance problems experienced with the machines used in this program would be eliminated.

- 6.2.2 The spraying equipment as developed and used in this program will produce uniform spray-coated surfaces nearly as fast as an automated spray system. It is the need to inspect and touch-up and the drying of the sprayed Neoprene-latex and not the actual spraying time which determine the time sequence between the successive coats. With the use of one spray gun, the woven fabric casing can be sprayed in less than 30 minutes. This spraying time is faster than the required drying time for a Neoprene-latex coat.

In order to speed the spray-coating of Neoprene-latex (if larger quantities are being processed) several support stands for casings could be provided. These stands could be converted into drying ovens by closing the curtains and circulating heated dry air in the enclosure. (See Figure 9.) Workers could spray one or several casings at the same time from one or more high pressure Neoprene-latex spray containers.

- 6.2.3 The Radalon spray materials contain Toluol or Xylol solvents which present fire hazards and are mildly toxic. These materials require a spray area and personnel protection which comply with Occupational Safety and Health Act (OSHA) requirements as well as Fire Prevention standards.

- 6.2.3.1 Further development could be devoted to replacing the Radalon weather resistant surface coatings with compatible spray materials which utilize less hazardous solvents.

- 6.2.3.1.1 During the evaluation of the adherability samples it was apparent that the woven fabric yarn surface treatment (dip) effectiveness diminishes with elapsed time. The aqueous P-18 dip used for the yarn treatment for this development program also made the yarns more coherent by bunching the yarn filaments tightly together, making them stiffer and preventing the sprayed Neoprene-latex from penetrating into the yarn surface filament. The age-diminished chemical effectiveness of the dip resulted in little cross linking with Neoprene-latex spray coats, and the lack of spray penetration probably reduced the mechanical bond of spray-coat to yarns. To improve the adherability of spray coatings to the casing fabric, it is recommended that an improved yarn dip system be investigated possibly including a final treatment spray-coated on the casing prior to Neoprene-latex application.

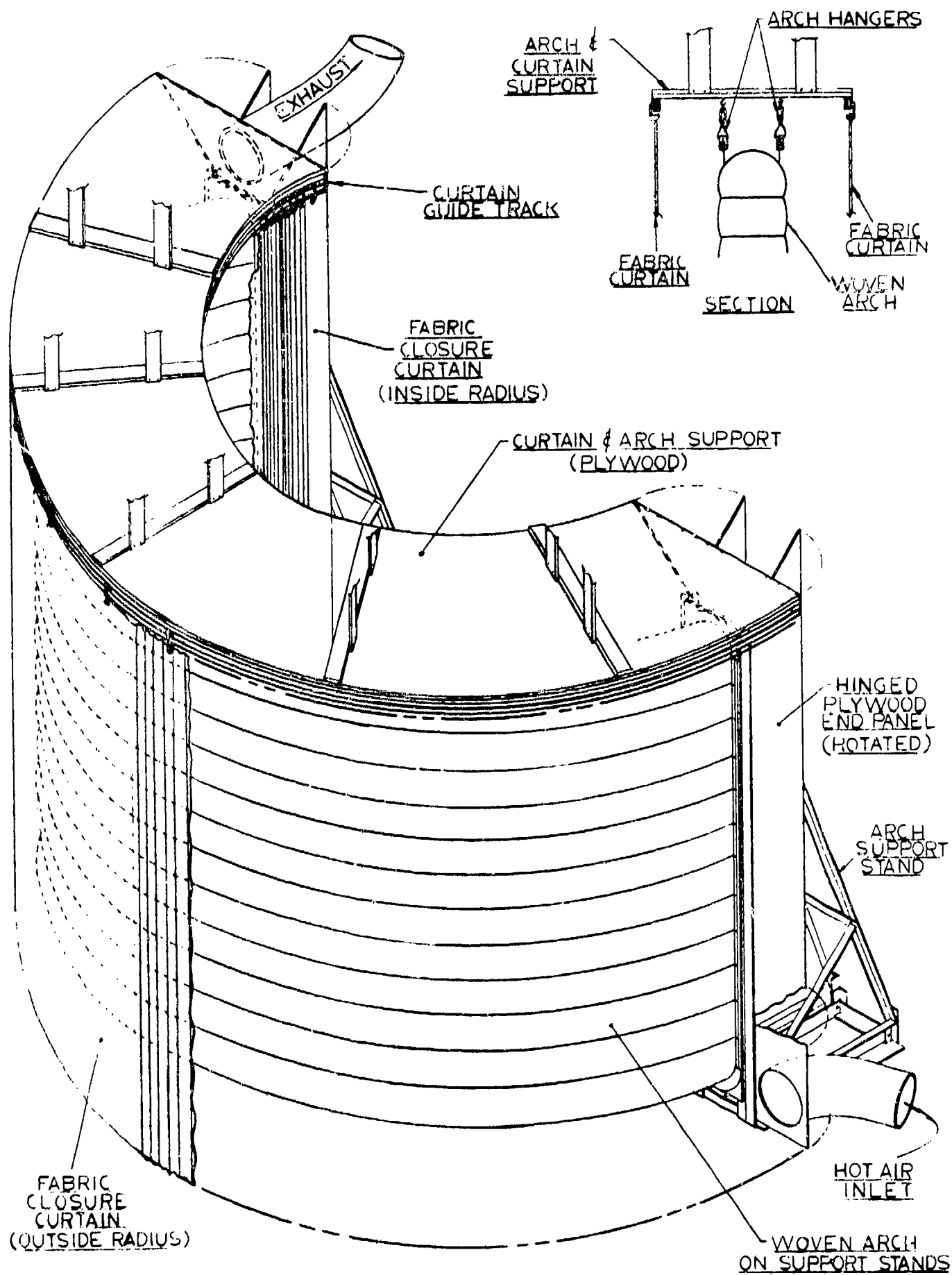


FIGURE 9: QUICK-DRY HOT AIR ENCLOSURE

6.2.5 Visual inspection of the top "Radalon" coating compound indicated that surface cracking could occur when sharply creased probably because of high tension loads at this folded areas. To improve this condition it is recommended that the "Radalon" be sprayed as procured (undiluted) and that the number of Radalon coats be increased from 2 to 3. This increased Radalon film thickness should distribute the tension loads from creasing over a greater thickness, thus decreasing the possibility of surface cracking. Increased thickness will add to the MUST shelter useful service life with a small increase in the section's weight.

6.2.6 A "travel card" should be provided to accompany every casing section through its manufacturing process. The time of completion together with responsible personnel would be recorded on the card for all significant fabrication and inspection steps on each part.

7.0 LIST OF REFERENCES

7.1 B.F. Goodrich Report No. 75-26-022, Manufacturing Methods Report of the Double Wall Air Inflated MUST Shelter, CDRL Sequence No. 3, U.S. Army Natick Laboratories Contract No. DAAG17-73-C-0139. NARADCOM Technical Report No. 7T-8 AMEL, 30 September 1975.

7.2 Woven Structures Final Report, Integrally Woven Fabric for Development of a Double Wall Inflatable Structure, B.F. Goodrich Co. Subcontract No. 48100. Report dated 27 June 1975 and appended to reference 7.1 preceding.



FIGURE 10: ASSEMBLED MUST SHELTER UNIT FABRICATED OF 3-D SPRAY COATED FABRIC



FIGURE 11: INTERIOR OF THE ASSEMBLED MUST SHELTER UNIT

APPENDIX

DEPARTMENT 2060

PHYSICAL TESTING LABORATORY

3-D UNCOATED WOVEN FABRIC WARP DIRECTION

Fabric No. _____ Width _____ Tested _____

Roll No. _____

PER CENT
ELONG

130

120

110

100

90

80

70

60

50

40

30

20

10

0

2-4x4 gph - 3
4.243 gms

92 - 1020
1015
1021
1020
1022

POUNDS

Lot 86056-1818
824

Warp - increased fabric
from woven structures

2.15					
2.45					
2.25					

METHOD: Sample -

H. L. Scott Fabric Machine. Separation of jaws 12" per minute. Speed of Chart 24" per minute.

Tested By

12/3/74

JR

Checked By

58

Approved By

DEPARTMENT 2060
 PHYSICAL TESTING LABORATORY
 3-D UNCOATED WOVEN FABRIC FILL DIRECTION

Fabric No. _____ Width _____ Tested _____
 Roll No. _____

PER CENT
 ELONG

130

120

110

100

90

80

70

60

50

40

30

20

10

0

50

100

150

200

250

300

350

400

450

500

550

600

650

700

750

800

850

900

950

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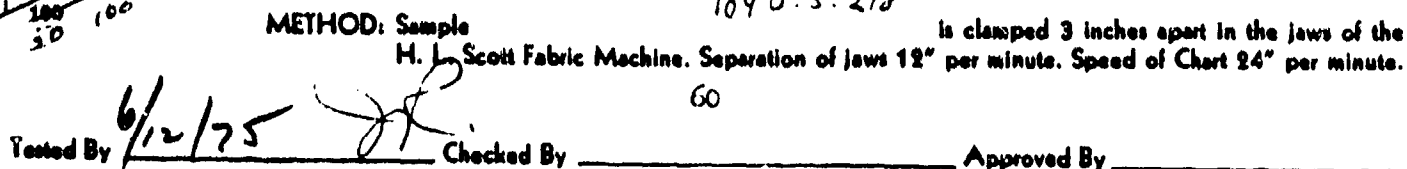
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14650

14700

14750

Fabric No. _____ Width _____ Tested _____
Roll No. _____



DEPARTMENT 2060
 PHYSICAL TESTING LABORATORY
 3-D SPRAY COATED WOVEN FABRIC FILL DIRECTION

Fabric No. _____ Width _____ Tested _____
 Roll No. _____

PER CENT
 ELONG

130

120

110

100

90

80

70

60

50

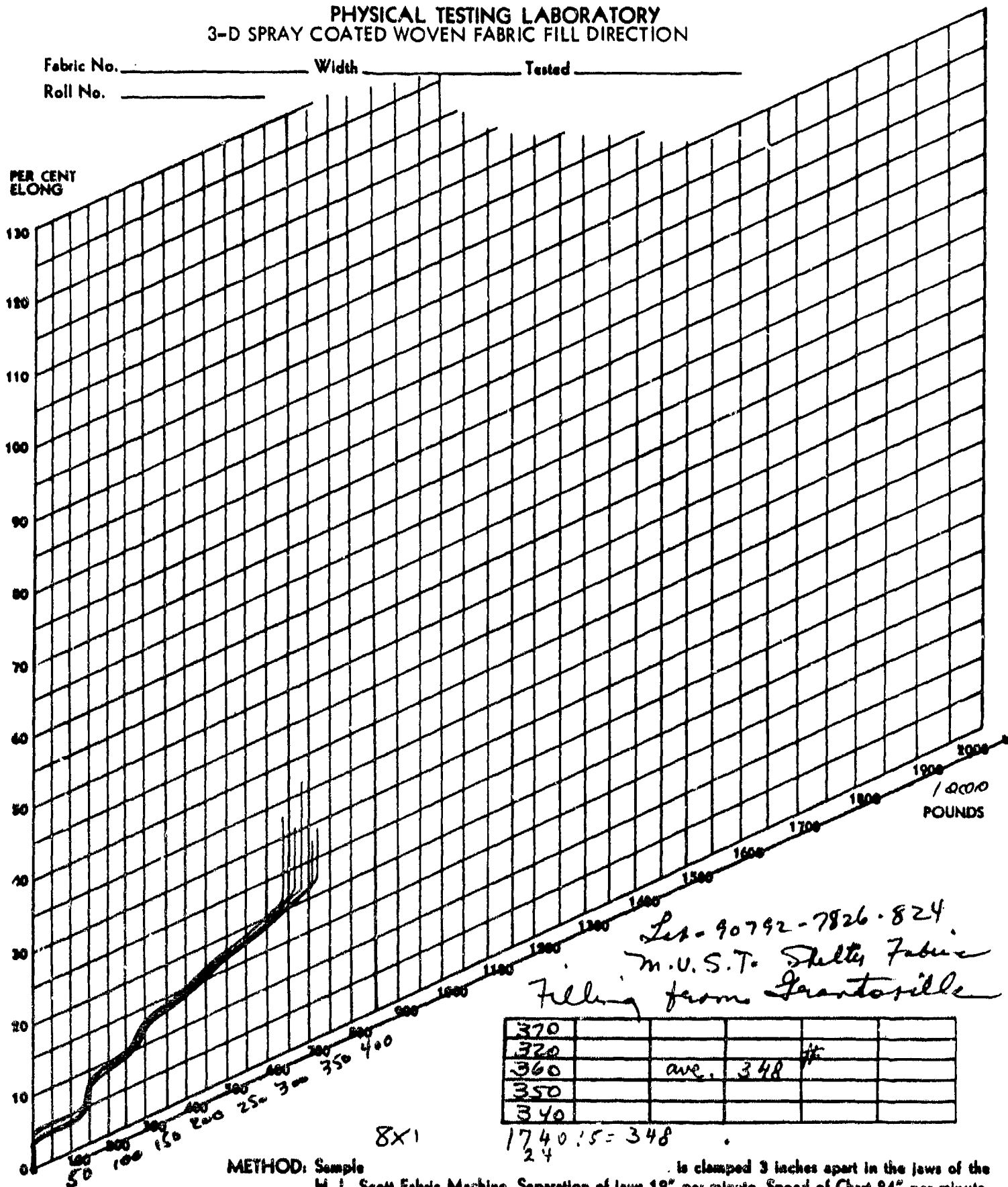
40

30

20

10

0



370				
320				
360	ave.	348	#	
350				
340				

$$1740 : 5 = 348$$

METHOD: Sample

H. L. Scott Fabric Machine. Separation of jaws 12" per minute. Speed of Chart 24" per minute.

Tested By 6/12 JR Checked By _____ Approved By _____

CHECK VALVE LEAK TEST CALCULATIONS

Allowable maximum air loss 25 c.c./min. at 1 psi air pressure.

Each valve was pressure tested for 10 minutes.

Starting pressure 27.7 inches column of water (1 psi). The container pressure after 10 minutes should not fall below 22.7 inches.

Container volume: 1,400 cubic inches

General gas law $PV = w RT$

where :
P = pressure (psi)
V = volume (ft³)
w = air weight (#/ft³)
R = air constant (53.33 ft - lb./lb per deg)
T = absolute temperature (460°F + 75°F)

Initial mass of air in the tank at 1 psi:

$$m = \frac{(P)(V)}{(R)(T)} = \frac{(15.7)(144)(1,400)}{(53.33)(535)(1,728)} = 0.06418\#$$

Allowable air loss in 10 minutes:

$$= (25 \text{ c.c.}) (10) = 250 \text{ c.c.} = \frac{250 \text{ c.c.}}{16.39 \text{ cc./in.}^3} = 15.25 \text{ cu. in.}$$

Allowable air mass loss (max.) =

$$m = \frac{P.V.}{R.T.} = \frac{(15.7)(144)(15.25)}{(53.33)(535)(1,728)} = 12$$

$$m = 0.00070\#$$

Initial mass less mass loss = Final mass

$$\begin{array}{r} 0.06418 \\ 0.0007 \\ \hline \text{Final mass } 0.06348 \end{array}$$

$$P.V. = m RT$$

$$\text{Pressure} = \frac{m RT}{V} = \frac{(0.6348) (53.33) (535) (1728)}{(.144) 1400}$$

$$\begin{array}{rcl} P = & 15.52 \text{ psi} & \text{(Starting pressure)} \\ & 14.70 \text{ psi} & \text{Atmospheric pressure} \\ \hline & 0.82 \text{ psi} & \text{Pressure in container} \\ & 0.18 \text{ psi} & \text{is the pressure loss} \end{array}$$

.18 psi correspond to 5" column of water

$$\begin{array}{rcl} \text{Monometer reading for 1 psi} & = & 27.7 \text{ inches} \\ \text{Allowable loss} & & 5.0 \text{ inches} \\ \hline \text{Lowest monometer pressure} & = & 22.7 \text{ inches} \\ \text{after 10 minutes} & & \end{array}$$

BFG

EFFECTIVE 2720
SUPERSEDES NEW

INDUSTRIAL ADHESIVE PRODUCTS

"RADALON" COATING SERIES

B.F. Goodrich "Radalon" Coatings meet the requirements of MIL-P-9503B. They are permanently elastic coatings which are used as decorative and protective finishes on rubberized fabric and rigid polyester radomes, inflatable structures and automotive rubber such as extrusions and sponge weatherstrip. With suitable primers, they can also be used on rigid surfaces such as wood, metal and glass.

"Radalon" coatings have excellent flexibility. They protect the base rubber against ozone and weathering. "Radalon" coatings are transparent to the frequencies used in radar equipment and may be applied to protective structures sheltering radar antenna equipment.

For most applications, "Radalon" coatings will adhere to fabric, sponge and rubber goods without the use of a primer. B.F. Goodrich A-862-B adhesive is recommended for use as a primer on metal, polyester (rigid radomes), glass and other non-porous surfaces. Primer is not usually required for nitrile, neoprene, SBR or natural rubber.

The following "Radalon" coatings can be furnished to match lusterless colors listed in Federal Color Standard No. 595. Minimum production quantity of any color is 50 gallons. Use A-625-B with A-1202-B accelerator as a base coat for colored coatings on inflatable structures.

<u>Product No.</u>	<u>Color</u>	<u>Federal Color Standard #595</u>
A-625-B	White	37875
A-677-B	Flat Black	37038
A-738-B	Brown	30045
A-802-B	Light Grey	36307
A-803-B	Dark Grey	37173
A-885-B	Olive Drab	34086
A-1159-B	Aviation Orange	32197
A-1162-B	Sand	32630
A-1249-B	Grey	36270
A-1263-B	Forest Green	34108
A-1290-B	Bermuda Sand	36357
A-1309-B	Dark Grey	36152
A-1318-B	Light Green	34516
A-1344-B	Olive Drab	34096

(Over)

Construction Adhesives... Plastisols and Latexes... Special Rubber Products



ADHESIVE PRODUCTS

AKRON, OHIO 44318

SOLUTION PROPERTIES - A-625-B

Base	Hypalon* Rubber
Color	White
Viscosity	Ford Cup 1/4" Orifice - 8 to 15 seconds at 76°F
Total Solids	24 to 26%
Specific Gravity	1.00 (Calculated)
Thinner	Toluol or Xylol
Flash Point	44°F (Approximate)
Coverage -	
Calculated	230 sq.ft./gal./mil
Application Average	150 sq.ft./gal./mil

CURE SYSTEM

"Radalon" coatings are designed to cure slowly in outdoor service, eventually becoming insensitive to solvent. Repainting before the coating is fully cured may result in lifting or wrinkling of the prior coating.

A-1202-B accelerator should be used as an additive (4 fluid ounces per gallon) when faster cure is desired. The accelerator should be used in manufacturing operations for production of articles which can be packaged and shipped with minimum risk of blocking and physical damage from handling. This also permits repainting within a short period of time. Dusting with talc is recommended for protection against blocking where parts are in direct contact under pressure.

Accelerated coating solution should be used within approximately one week. Upon aging, gradual increase in viscosity will occur; however, the physical properties of the cured film will not be adversely affected. Hot weather will speed the rate of viscosity growth.

APPLICATION INSTRUCTIONS

For New Flexible Air Supported Radomes, Coated Fabrics, Rubber Products

1. Surfaces to be coated should be clean. Care must be taken to remove any loose dirt or dust prior to application. Rinse thoroughly when a detergent is used to clean the surface.
2. Stir coating thoroughly immediately prior to application.
3. The preferred method of application is by spray:
 - a. The air temperature for conventional spray application should be 50°F or above.
 - b. Reduce two volumes of coating with one volume of toluene.

* Registered Trade Name - E.I.duPont.

"The data, statements and recommendations (shown for information only) are based on tests which are believed to be reliable. Since we have no control over the end use of our products we cannot guarantee the end results. We suggest the user determine whether the product is suitable for his own production conditions."

- c. Spray successive coats until desired thickness is obtained without sagging. Dry to touch between coats. For maximum adhesion, allow 30 minutes between coats. Work can be handled after 5 minutes dry time. For most applications, 150 sq.ft./gallon coverage can be expected.

Note: Binks #18 or #19 spray gun equipped with #66 fluid nozzle and #66SD air cap is a suitable setup. The suggested atomizing pressure is 40 psi. The gun should be adjusted to give a 10 to 12" fan when held 12" from the work. Pot pressure depends on size and length of fluid line, and is best determined by trial.

When applying by roller or brush, extreme care must be taken to prevent an orange-peel finish and tendency of paint to "pick-up" when the applicator passes over a previously painted area.

For New Rigid Radomes (Polyester), Metal, Glass and Other Rigid Surfaces

1. Surfaces must be free of oil, wax, etc. Polyester should be lightly sanded.
2. A primer is required to insure good adhesion and desired degree of protection to rigid surfaces. The following primers are recommended:
 - a. A-862-B provides excellent adhesion to most rigid surfaces where corrosion is not a consideration. The primer may be applied by brush as-is, or by spray if reduced with 3 volumes of toluene. Allow 3 to 5 minutes dry time between coats. Two coats are recommended. Use same equipment as indicated above, except use 30 psi atomizing pressure. Metal panels treated with MIL-P-8585 zinc chromate primer over "wash primer" must be primed with A-862-B before application of A-625-B in order to get adhesion. Application of A-625-B over A-862-B primer must be by spray. Follow spray instructions in Step 3, Page 2.
 - b. KE-2202 A and C is a two-part flexible epoxy primer which considerably improves the corrosion-weather resistance of any "Radalon" coating system. The primer has excellent adhesion to metal parts as well as to polyester fiberglass panels of radome structures.

Mix Part C into Part A (equal volumes), apply by any method and let it cure 24 hours before application of A-625-B. Forced drying at elevated temperature may be used to speed the rate of cure.

In new radome structures, the use of B.F. Goodrich A-862-B rubber base primer is recommended as a tie-coat between KE-2202 and A-625-B "Radalon" coating to provide resistance to wind load flexing and thermally induced dimensional changes.

For Reconditioned Radome Structures

1. Surface Preparation

- a. Scrub the surface with a hard-bristled brush using detergent and water to remove accumulated particles which interfere with electronic transparency and adhesion.
- b. Rinse thoroughly with fresh water.

2. Application of Coating

a. At 50°F or above -

To avoid lifting, apply a first coat of "Radalon" using a spray technique where this coat is applied to minimize the exposure to solvent. Do this by applying a thin, fast-drying coat with the spray nozzle at maximum tolerable distance from the target. Allow this coat to dry and proceed, using the previously described procedure.

In low temperature climates, use A-1202-B accelerator to compensate for the adverse effect of low temperature on the rate of cure.

b. At temperatures below 50°F -

To avoid lifting, apply a primer coat of KE-2202 A and C and allow to cure until it becomes resistant to wiping with toluene. The approximate cure time is 24 hours. Proceed with spray application of "Radalon" coating using the previously described procedure.

WARNING -- FLAMMABLE SOLUTION!

Keep away from heat and open flame.

Keep containers closed.

Use with adequate ventilation.

Avoid prolonged breathing of vapor.

Avoid prolonged or repeated contact with skin.

IN ADDITION TO THIS PRODUCT, THE B.F.GOODRICH GENERAL PRODUCTS COMPANY OFFERS A WIDE RANGE OF ADHESIVES, COATINGS, LATICES AND PLASTISOLS FOR MOST BONDING AND COATING APPLICATIONS. CONTACT YOUR LOCAL GOODRICH REPRESENTATIVE OR WRITE US AT 500 SOUTH MAIN STREET, AKRON, OHIO 44318, FOR DETAILS.